PROJECTS ■ THEORY ■ APPLICATIONS ■ CIRCUITS ■ TECHNOLOGY

By Malestrom 13-09-2008

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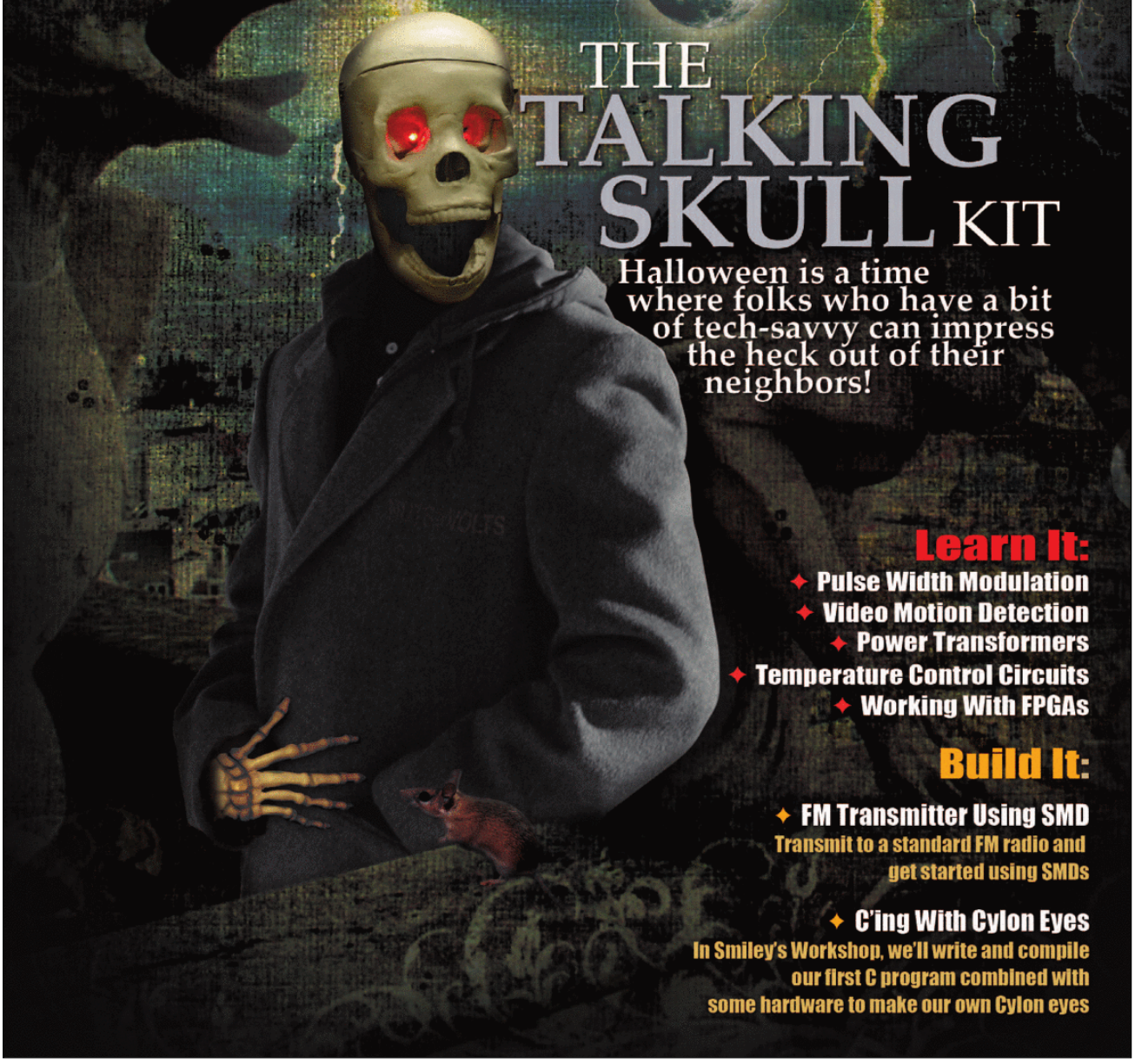

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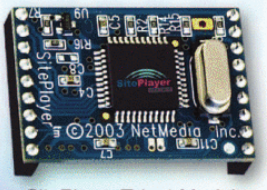

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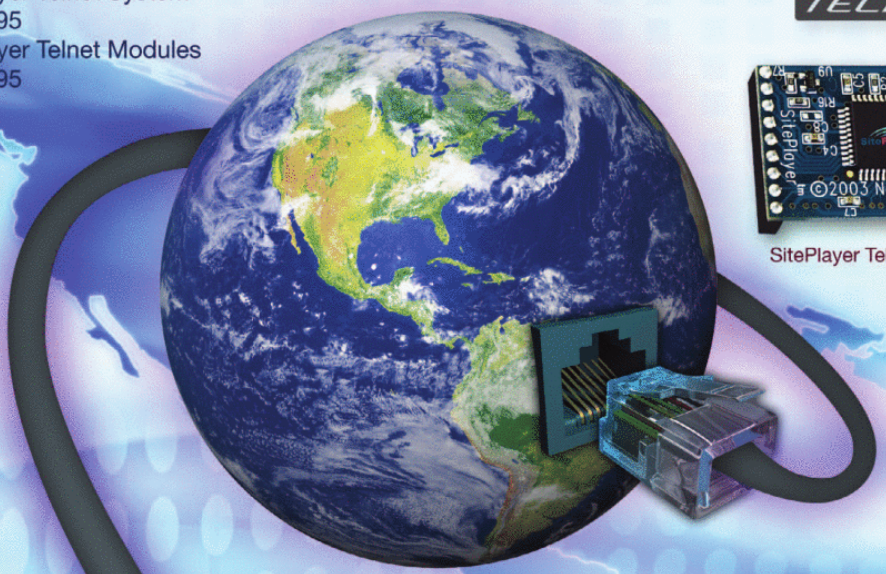

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NetBurner Customer Feedback: Why are you using NetBurner?

The excellent out-of-the-box experience

I would like to comment on the quality of a product that I purchased - the MOD5270. I've purchased products in the past from other companies that claim "plug and play" functionality. Usually this means plug it in and try to figure out why it doesn't work. With the MOD5270 I literally plugged in the power, connected it to my router, and ran the factory demo.

I am also impressed with the number of example applications that are included and the fact that all the development tools are included. It was nice to be able to create a new project, import one of the examples, and run it within 5 minutes.

Keith Gilman, Sr. Design Engineer

The complete hardware and software solution

We did a previous project using different companies for the RTOS, network stack, and compiler. Yeah, three vendors and all the associated finger pointing. We had to buy the flash file system as an extra/add-on. We put an 8M flash device on our processor bus, and a guy had to write a driver for the device (data register, command register, poll the ready bit, blah, blah), it was a 3+ month job. I thought I was in for the same thing. Thanks to you, we will drop the soldered-on Flash and put on the SD connector which will be ready to roll with your file system that runs 'right out of the box'. I was sweating about all the Flash work, and now its gone.

John Ramsy, Project Engineer

The active forum filled with NB Gurus

NetBurner offers a highly versatile and affordable solution set for embedded design, remote control, and product development. From the very active user forum (with Netburner gurus in attendance), to the great IDE and tool chain. NetBurner is the first and only solution for TCP/IP-Internet-Web product automation in my book.

Chris Ruff, Software Engineer

The quality of the technical support

I've been really impressed with the quality of the tech support. The guys answering the questions are right on and super helpful (probably has to do with your policy of having the engineers handle the tickets).

Nicolae P. Costescu, Project Engineer

The full-featured tool set, examples, and documentation

The device and the NetBurner tool-set far exceeded our expectations. I spent a week familiarizing myself with the NetBurner tools, and then I wrote a first-cut of the original application that I had envisioned for the SB72EX. As it turned out, two of the example applications formed the core of the networking capabilities of my application. The bulk of my time was spent implementing a simple command interface to cause the device to interrupt its default IP-to-serial modes to receive and store a stream of data and then FTP that data to a remote server.

The NNDK interface to the IP/socket facilities of the SB72EX proved to be the simplest part of the application - the interface is straightforward and the documentation is excellent (the large collection of application examples didn't hurt). Midway through my efforts I had a couple of questions that I elected to send to the NetBurner support group - the response was almost immediate, the person(s) responding were obviously knowledgeable and experienced - how refreshing!

The SB72EX device and (perhaps more importantly) the NetBurner tool-set have proven to exceed our immediate needs and have started the gears turning as to how we might use them to address other requirements.

Fred Craft, Software Engineer

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■ *By Jim Stewart*

●●●● Advanced Level

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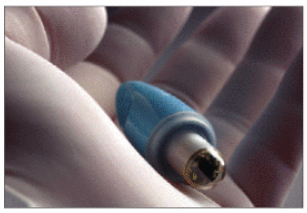

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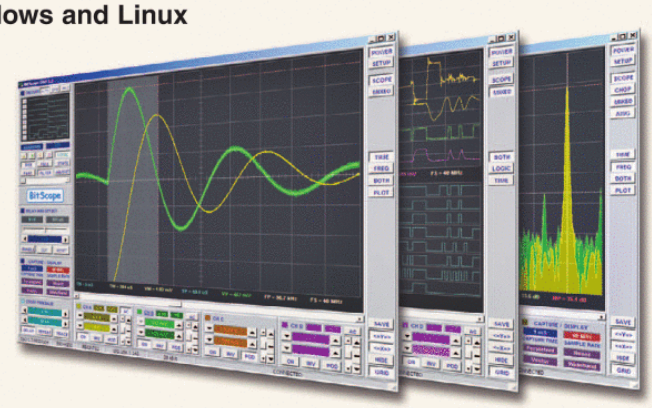

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DEVELOPING PERSPECTIVES

by Bryan Bergeron, Editor

Economical Electronics

In the current economic downturn, it may be difficult for you to rationalize spending what's left of your dwindling disposable income on electronic components, test equipment, and other non-essentials. However, your electronics avocation needn't be an all-or-nothing proposition. There are numerous ways of cutting costs without diminishing your enjoyment. In fact, if your focus is circuit design, then you'll probably find the engineering challenge of getting the most from affordable components more rewarding than simply ordering and using the latest generation chips. And there are also options for construction enthusiasts.

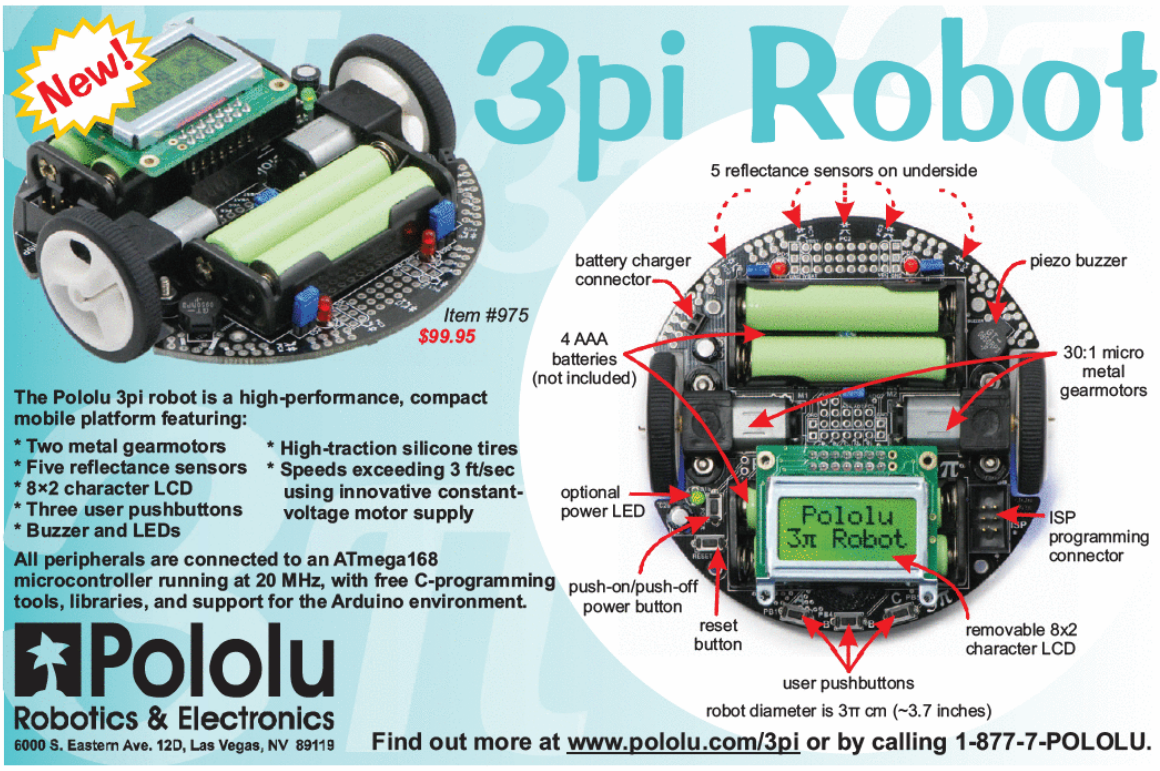
Doing more with less is nothing new to those of us who work in electronics. Most electronic engineers face economic pressure on a daily basis from both management and the market. As enthusiasts, we often have the luxury of working at our leisure, of relatively flexible budgets, and of over-engineering circuit designs so to cover any likely operating constraints. In comparison, a five cent difference in the cost of a component can destroy the profit margin on a product run of 50,000, and can make the difference between commercial success and failure. So what can you do, as an electronics enthusiast, to minimize cost? I suggest the following:

- ***Design With Cost in Mind***

If you're designing, for example, an audio circuit, do you really need the latest, ultra-low-noise op-amps? Can you get by with an inexpensive, somewhat older chip without a discernable difference in quality? Are the components in your design available from suppliers in single units? Do you really need a printed circuit board, or can you achieve the same results with an all-purpose board? Are you over-embellishing your design with marginally useful LCD displays, meters, LEDs, and switches?

- ***Shop Wisely***

Use discount components and enclosures whenever possible.



Consider purchasing components from discount suppliers such as All Electronics (**www.allelectronics**) and numerous other vendors on the Web and listed in this magazine. While many of these discount suppliers offer seconds of lesser quality than components from Mouser, Digi-Key, or Jameco, you may not notice a difference in performance.

• ***Plan Ahead***

Regardless of where you purchase components, plan ahead to avoid unnecessary shipping and handling charges that can inflate the cost of a project. It's often cost-effective to purchase the components for your next two or three projects at the same time, since you'll save on shipping (relative to single purchases) and get a break for bulk purchases. Similarly, you can save on shipping by combining purchases with your friends.

• ***Repurpose When Possible***

Although working with new components and circuit designs is a pleasure, it can also be expensive. Keep a modest junk box filled with your discarded or newly found power supplies, circuit boards, and components. A soldering iron, heatsink clamp, and either a solder sucker or braid made from discarded coaxial cable are all you need to extract components cleanly from a circuit board. As a youth, I saw to it that every discarded radio and TV for blocks around contributed to my parts bin.

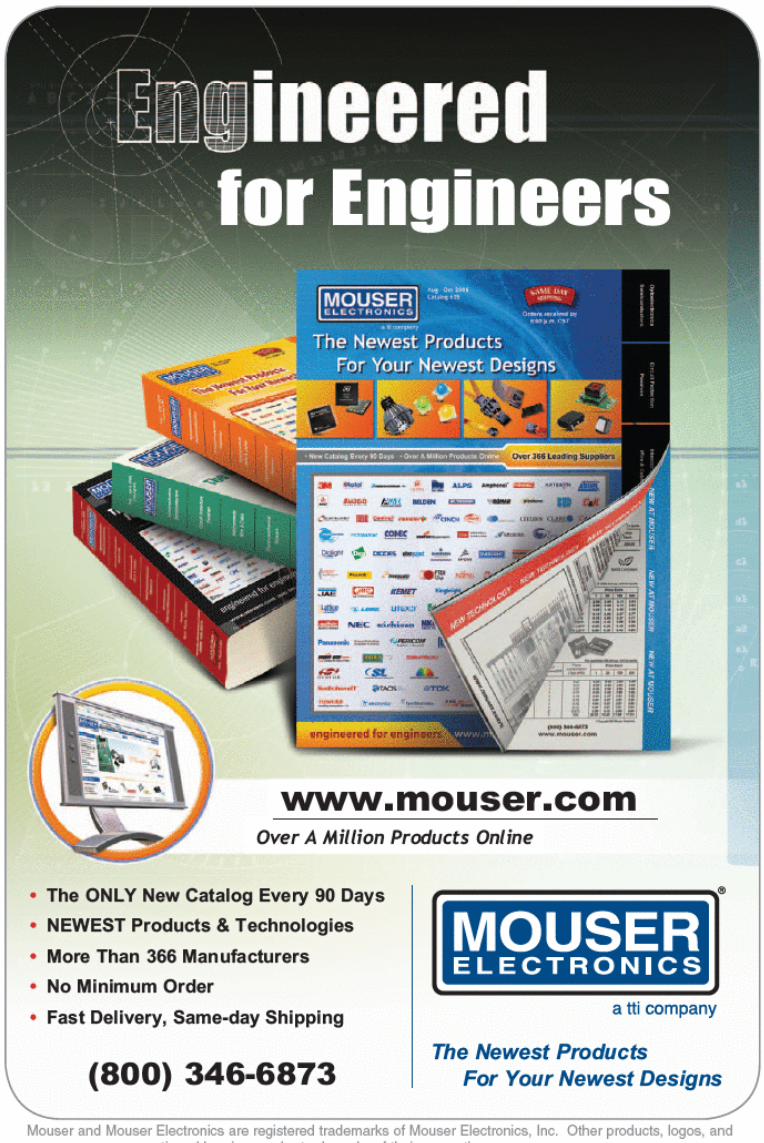
• ***Use Your Imagination***

When shopping for enclosures and hardware, don't limit your searches to traditional sources. You can often find equivalent supplies in non-electronic markets. For example, I recently searched for three aluminum discs for a robot project. A popular online robot hardware supply house listed 18″ discs for $48 each, plus shipping. In contrast, a visit to my local hardware store turned up 16″ aluminum pizza pans for $15. Armed with a brand and product name, I searched on eBay and found the same pans — three for $30, including shipping.

• ***Try Kits***

If your focus is construction, then consider one of the low-cost kits from the *Nuts & Volts* online store or one of our many advertisers. Kits are an economical alternative to piecemeal construction, in part because the kit suppliers buy in bulk, and you only have to pay postage from one source. In addition, you won't find yourself 90 percent through a project to find you forgot to order a part.

I'd like to feature low-cost projects for cost-conscious readers in future issues of *Nuts & Volts*. If you have an innovative project that illustrates how to get the most out of an electronics budget, then please consider sharing your work with your fellow readers. I look forward to hearing from you. **NV**



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READER FEEDBACK

BREAKING THE CODE

I enjoyed the "Remotely Programmable Power" by Paul Lapsansky (*N&V*, June '08). After all, who has a hobbyist workbench without a PC sitting on or near it? After reading the article, I followed the links to learn more about the project's firmware (installed in the PPS) and the application software that runs on the PC (and is needed to set up and control the PPS).

Unfortunately, there are only two files; the HEX code for the PIC and an executable that runs under the PC OS. I learned nothing from them, and probably will abandon any plans to build the project, as the 'software engine' is an un-hackable mystery "black box."

I don't understand why these details are kept secret. They have little commercial value beyond this project and would have made a great learning experience for those of us considering PC-related projects of our own.

The opportunity to hack the firmware and the PC application would have been very welcome, even if the print magazine was limited to a flow chart or block diagram of the software's internal operation. Fully documented source code by download from the magazine's website would have been very helpful, too!

In the interest of helping other readers, can we have full disclosure of software (and firmware) on future projects? I'd like to think a progressive publication like *N&V* is "open source" and not modeled after the folks headquartered in Redmond, WA.

Peter J. Stonard
Campbell, CA

*RESPONSE: Peter, I agree with you on the benefits of having access to the source code to better understand how the project works. It has been my intention to release the source code for both the firmware and executable once I had the opportunity to clean up and add some comments to the code. Unfortunately, other projects and family obligations had delayed me in completing. The source code is now available for download from both my website (**www.rad220.com**) and from the Nuts & Volts FTP Library, as well. The PPS program is written in Emergence Basic from Ionic Wind Software which is a freeware Basic compiler that can be downloaded from the their website (**www.ionicwind.com**). The firmware is written in mikroBasic from mikroElektronica. You can download a demo version of their Basic compiler from their website (**www.mikroe.com**). The demo limits the hex output to 2K but this is sufficent to compile the PPS firmware. I left out the code for the bootloader since this code is included with the mikroBasic compiler. See the README file I've included with the source code for information on compiling and working with the bootloader.*

Paul Lapsansky

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FOUNDER/ASSOCIATE PUBLISHER
Jack Lemieux

PUBLISHER
Larry Lemieux
publisher@nutsvolts.com

ASSOCIATE PUBLISHER/ VP OF SALES/MARKETING
Robin Lemieux
display@nutsvolts.com

EDITOR
Bryan Bergeron
techedit-nutsvolts@yahoo.com

TECHNICAL EDITOR
Dan Danknick
dan@teamdelta.com

CONTRIBUTING EDITORS
Jeff Eckert, Vern Graner, Joe Pardue, Jon Williams, Ed Driscoll
Russ Kincaid, Fred Eady, Chuck Hellebuyck, Paul Verhage, Jim Stewart

CIRCULATION DIRECTOR
Tracy Kerley
subscribe@nutsvolts.com

SHOW COORDINATOR
Audrey Lemieux

MARKETING COORDINATOR WEBSTORE
Brian Kirkpatrick
sales@nutsvolts.com

WEB CONTENT
Michael Kaudze
website@nutsvolts.com

PRODUCTION/GRAPHICS
Shannon Lemieux
Joe Keungmanivong

ADMINISTRATIVE ASSISTANT
Debbie Stauffacher

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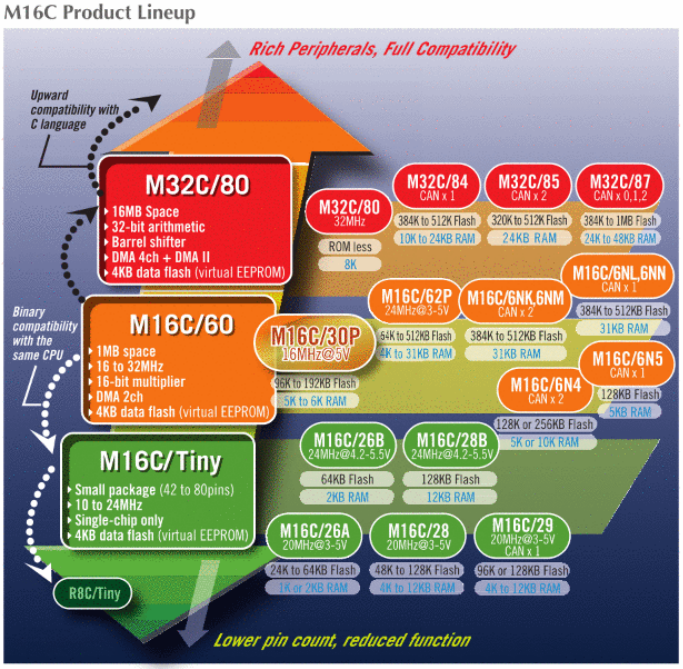

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*Source: Gartner "Semiconductor Applications Worldwide Annual Market Share: Database" Hiroyuki Shimizu, 27 March 2008, GJ08218 ＊This is 2007 ranking

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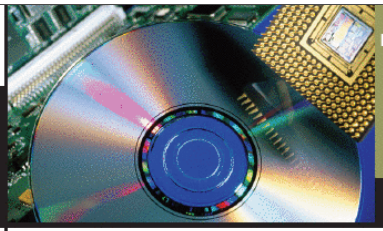


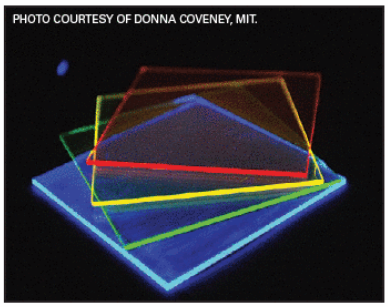
TECH KNOWLEDGEY 2008

EVENTS, ADVANCES, AND NEWS

■ BY JEFF ECKERT

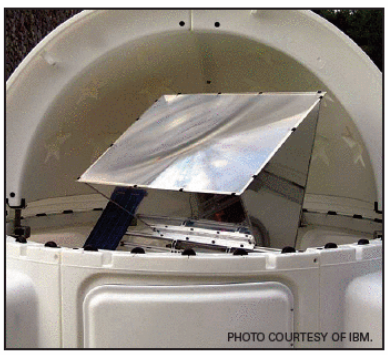
ADVANCED TECHNOLOGY

SOLAR CONCENTRATION REVISITED



■ Organic solar concentrators that collect and focus different colors of sunlight may soon be integrated into cost-efficient power systems.

The idea of harnessing concentrated sunlight is not a new concept — far older than our childhood pastime of frying ants with a magnifying glass. According to legend, Archimedes used polished bronze shields as mirrors during the siege of Syracuse, circa 214 BC, in an attempt to repel the invaders. Unfortunately, it didn't work all that well, as the city eventually fell, and Archimedes was slain by a Roman soldier. Likewise, modern attempts to harness daylight have met with limited success, particularly for generating electricity.



■ IBM's breakthrough concentrator photovoltaic cells could bring more watts at lower cost.

Focused sunlight is nice for drying fish and even powering steam engines, but the associated heat has about the same effect on semiconductors as it has on ants. In the 1970s, scientists experimented with dye-impregnated plastic sheets that were designed to capture photons on the flat surface and channel them toward the edges, thus concentrating the energy while avoiding the heat problem. But the dyes weren't stable enough, and the photons tended to be reabsorbed by the plastic.

In July, however, some MIT engineers announced a new twist on this long-abandoned technology. The new method uses dye-coated glass to collect and channel the photons toward an array of solar cells mounted along the edges. It seems that using thin, concentrated layers of dyes on glass works better than filling plastic with lower concentrations, and the materials are cheaper.

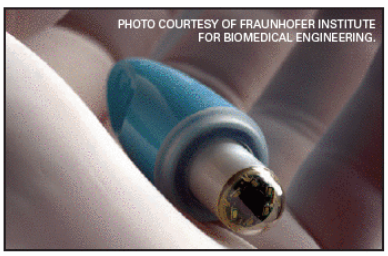
One proponent has predicted that we could be as little as three years away from a commercial product that allows a building to draw energy from tinted windows and roof-mounted panels. The hitch seems to be that they have yet to develop dyes that can endure the 20 to 30 years of exposure required for a viable product. Coming at it from another direction, IBM earlier this year announced a breakthrough in concentrator photovoltaics (CPV) in which a large lens focused a record-setting 230W (equivalent to 2,300 suns) onto a one sq cm solar cell. That energy was then converted into 70W of usable electrical power, which represents about five times the power density developed in typical solar farms. The trick was overcoming the aforementioned heat issue, which they accomplished using a "liquid metal" thermal cooling system originally developed for the microprocessor industry.

The system uses a thin layer of a gallium/indium compound sandwiched between the cell and a copper cooling plate. The layer transfers heat so efficiently that the temperature of the chip is reduced from 1,600 to 85°C. If the company can overcome the usual challenges in moving "from lab to fab," the result could be a system that cuts the number of photovoltaic cells and related components by 90 percent, achieving similar cost savings.

MAGNET-CONTROLLED INTERNAL CAMERA

The camera-in-a-pill concept has been around for several years, by which doctors drop a miniature still camera down your throat, take snapshots of your innards, and transmit gooey Kodak moments to an external receiver. This is pretty useful for locating hemorrhages and cysts in your intestines, but the gutcams — weighing about 5 g —tend to drop through your esophagus and down to the lower stomach wall too quickly to gather much information. As a result, patients who need a detailed

■ This pill camera can be magnetically steered to provide more detailed esophageal and stomach analysis.



examination of these organs still experience the thrill of having a comparatively thick endoscope shoved down their throats. However, the folks at the Fraunhofer Institute for Biomedical Engineering (**www.ibmt.fraunhofer.de**) have come up with a prototype system that allows the camera to be steered magnetically.

"In the future, doctors will be able to stop the camera in the esophagus, move it up and down, and turn it, and thus adjust the angle of the camera as required," according to team leader Dr. Frank Volke. "This allows them to make a precise examination of the junction between the esophagus and the stomach ... Now, with the camera, we can even scan the stomach walls."

The steerable unit is not much different from its predecessor, consisting of the camera, transmitter, battery, and a few cold-light diodes that work like flashbulbs. Its location can be controlled, however, via a hand-held device, and it can be kept in the esophagus for up to 10 minutes, even if the patient is sitting upright.

The camera — in case you were wondering — is disposable, so there is no need to collect it as it exits.

COMPUTERS AND NETWORKING

LENOVO ENTERS DESKTOP MARKET

Lenovo (**www.lenovo.com**) is perhaps best known for having acquired the ThinkPad laptop and notebook lineup from IBM in 2005. But the Chinese company recently entered the world market for desktops with its IdeaCentre K210, based on Intel Core 2 quad processors. Among the included bells and whistles is the VeriFace™ facial recognition technology that allows you to log in without a password, assuming that you did nothing the night before that drastically altered your appearance. It also comes with an antimicrobial keyboard that inhibits bacterial growth, so you will no longer have to worry about catching disfiguring diseases

PHOTO COURTESY OF LENOVO.

■ The Lenovo IdeaCentre K210 offers log-on via facial recognition and a germ-killing keyboard.

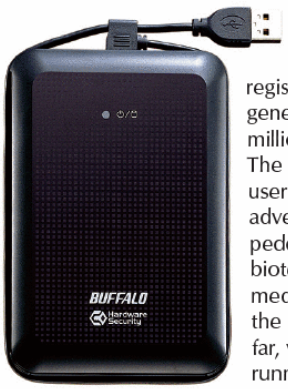
that reside on the fingers of friends and family members who share your computer.

Other available features include Intel Core 2 quad processors, Intel GMA integrated graphics, a Blueray HD-DVD combo, high-def audio, and the ability to upgrade to ATI Radeon 2600 XT for gaming.

In a somewhat mysterious marketing strategy, Lenovo does not sell its Bright Eye camera separately in the US, even though VeriFace does not work without one. So if you buy one of the new machines, be sure that the vendor bundles the camera as part of the package. The base price is $379, plus $229 for a 19-inch monitor, after rebate.

DATA SECURITY IN A MINI PACKAGE

Given the current epidemic of data breaches, secure transfer and storage is becoming ever more critical. One solution is the MiniStation DataVault from Buffalo Technology (**www.buffalotech.com**). What you get is a compact hard drive with hardware-based, government-grade, NIST-certified AES-128 encryption. Simply remove the drive from your computer and it automatically locks itself to prevent unauthorized access. The drive is packaged in a rugged case and wrapped in a floating and shock-absorbing interior to prevent impact damage, and the 3.3 x 5.2 x 0.9 inch (8.4 x 13.2 x 2.3 cm) unit weighs in at less than 8 oz, making it particularly useful for travelers. The device is Windows and Mac OS X compatible, includes mobile versions of the Firefox browser and Thunderbird e-mail client, and includes Buffalo's TurboUSB technology, which is said to increase transfer rates by up to 20 percent on Windows XP machines. You also get Memeo AutoBackup software. A recent check of Internet outlets found the 160 GB version available for about $105, and the 320 GB one for $156 and change.



■ The MiniStation DataVault provides up to 320 GB of encrypted storage.

PHOTO COURTESY OF BUFFALO TECHNOLOGY.

ANATOMICALLY CORRECT WEBSITE

There's no shortage of depictions of human anatomy on the Internet, but one that's even suitable for children has been launched by Argosy Publishing. The Visible Body™ (**www.visiblebody.com**) is billed as the world's first site providing interactive 3-D models of all human body systems. It allows visitors to "visualize and quickly and easily explore relevant areas of the human body, enabling them to explain how more than 1,700 anatomical structures — including major organs and systems — work together."

The site was initially aimed at educators and health and medical professionals, but has turned out to be of interest to more general audiences; as of this writing, more than 150,000 users have registered, and the site is generating more than three million page views per month. The site is currently free to users and supported by advertising, so if you want to peddle pharmaceuticals, biotech devices, or other medical paraphernalia, contact the marketing department. So far, you have to have a PC running Internet Explorer with

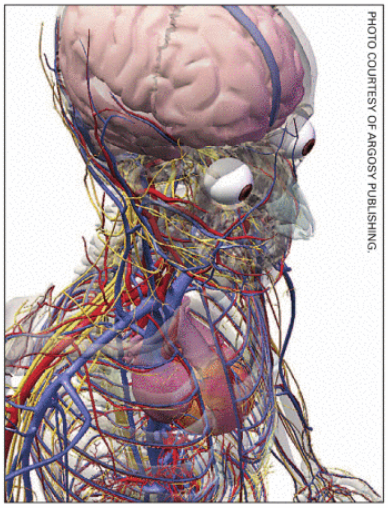


PHOTO COURTESY OF ARGOSY PUBLISHING.

■ The Visible Body lays claim to being the world's first free, Web-based 3-D interactive model of the human body.

Macromedia Flash and Anark Client plug-ins before you can probe their bodies, but Firefox and Mac OS X capability is "coming soon."

CIRCUITS AND DEVICES

LONG-LIFE PANEL POT

The standard panel potentiometer will last for something like 50,000 cycles, which is great if you're designing gas chamber controls or other equipment that isn't used on a regular basis. But if you deal with things like actuation proportional pedals,

PHOTO COURTESY OF VISHAY ELECTRONIC GmbH.

■ The P10L panel pot provides 500,000 cycles.

illuminated toys, audio systems, dimmers, machine tools, and an array of "white goods," you may be interested in the Sfernice P10L mini panel pot from Vishay (**www.vishay.com**).

This long-life device features a low temperature coefficient down to ±150 ppm/°C, a compact 9.6 mm footprint, and up to 500,000 operational cycles (equivalent to 11.4 operations per minute for five years — which is more often than Oprah opens and closes her refrigerator). The latter feature can reduce the need for part replacement, which increases reliability and lowers maintenance costs. The P10L's cermet element is more stable than carbon ones, and its 1,000 VRMS dielectric strength adds to reliability and performance. The device is available with four resistance values from 1 to 50K and offers one percent typical contact resistance variation. The operating temperature range is -40 to 100°C, allowing deployment in extreme environments. No price was quoted by the company, but it is described as "low-cost."

ZAP 'EM TO MUSIC

Perhaps you have been eager to mount an assault on vagrants, would-be attackers, or visitors who have worn out their welcome but just couldn't find a weapon that accessorizes properly with your designer wardrobe. Well, rejoice, because TASER International has unleashed its TASER® C2 personal protection device in new red-hot red, fashion pink, and leopard print color schemes. "Personal protection can be both fashionable and functionable," said Rick Smith, company CEO and founder. "The TASER C2 leopard print design provides a personal protection option for women who want fashion with a bite." But that's not all. A new carrying case for the C2 includes an MP3 player. With the TASER MPH (for music player holster), you can drown out a victim's screams with your favorite tunes (e.g., Nick Lowe's "Cruel to be Kind"). The C2 will run you about $285, plus $79.99 for the holster.

NV

■ Your personal TASER is now available with an MP3 carrying case.

PHOTO COURTESY OF TASER INTERNATIONAL.

INDUSTRY AND THE PROFESSION

ANOTHER WIN FOR THE GOOD GUYS

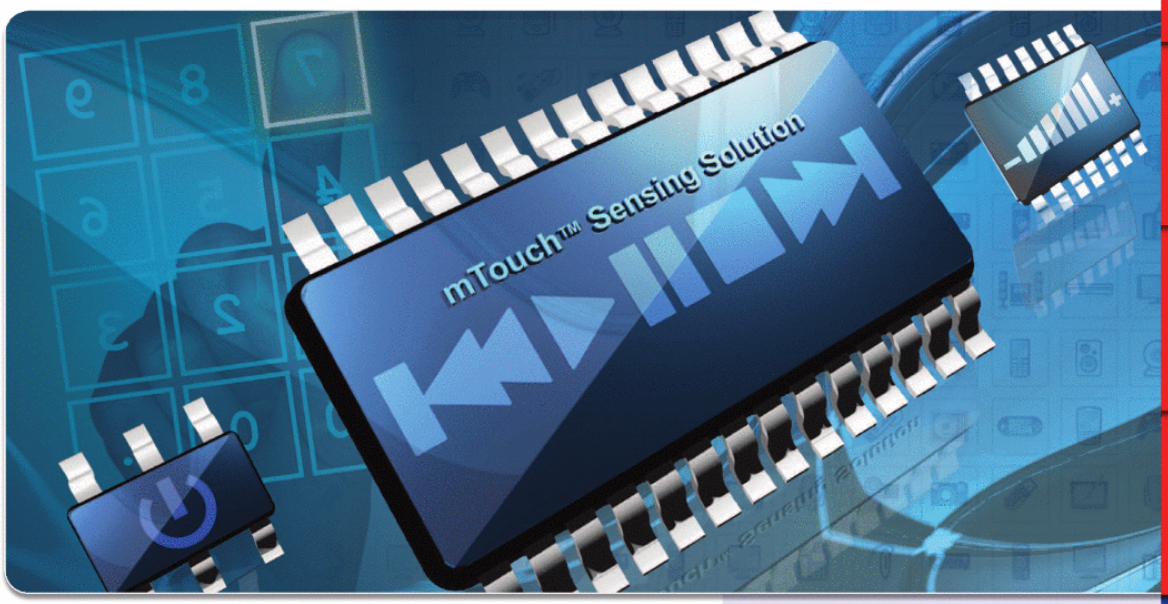
It may be just a drop in the bucket, but a Brooklyn man has been sentenced to 30 months in the slammer for circumventing AOL's spam filtering system and spamming 1.277 million subscribers. Adam Vitale, 27, was also ordered to pay $180,000 to AOL in restitution. An accomplice, Todd Moeller, has already been sentenced to 27 months. Vitale is reported to have had 22 prior convictions and also was involved in an online prostitution ring run via **craigslist.org**. The restitution comes to about $0.14 per spam victim, which AOL of course will credit to the victims. Of course.

MAC CLONE BUILDER SUED

Back in the July issue, we noted some legal questions in regards to the Open Computer PC — a $399 Mac clone from Psystar Corp. (**www.psystar.com**). The response from Apple turned out to be a 16 page lawsuit charging multiple copyright, trademark, breach-of-contract, and other violations based on Psystar's sales of machines preloaded with OS X 10.5 (Leopard).

In the suit, Apple is demanding that the company refrain from selling any more of the machines and turn over all of the profits derived from Leopard-equipped units. Psystar was also charged with loading a single copy of the OS on multiple machines — another licensing violation. As of this writing, the Psystar website was still up and running.

Capacitive Touch Sensing In a Flexible, Single-chip Solution



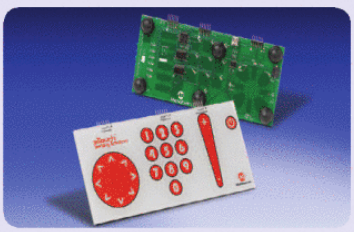
Capacitive touch interfaces provide an excellent way to add low-cost, reliable and stylish buttons into your design. Microchip Technology's mTouch™ Sensing Solution includes comprehensive development kits and a free diagnostic tool to make implementation easy and fast. Our free source code can be seamlessly integrated with your existing firmware on a single PIC® microcontroller – eliminating the need for additional controllers.

THE mTouch SENSING SOLUTION FEATURES:

- FREE license libraries and source code
- A FREE diagnostic tool
- Integration with 8- and 16-bit PIC microcontrollers
- Easy expansion, with support from 6 to 100 pins
- Low-power operation

GET STARTED IN 3 EASY STEPS

1. Visit the mTouch Sensing Solutions design center at www.microchip.com/mTouch
2. Download FREE libraries and source code
3. For a limited time, save 20% off a variety of touch sensing development tools when you purchase from www.microchipDIRECT.com and use coupon code **mTouch4U**.



Microcontrollers | Digital Signal Controllers | Analog | Serial EEPROMs

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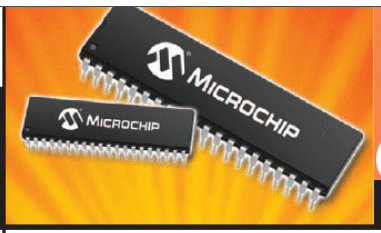
MICROCHIP



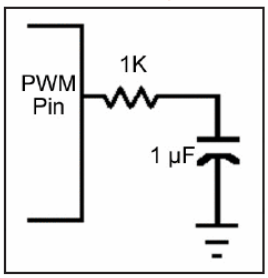
■ BY CHUCK HELLEBUYCK

PULSE WIDTH MODULATION

PULSE WIDTH MODULATION (PWM) is a common term in today's microcontroller (MCU) world. What PWM is and how you use it are the subjects of this column.

As I've covered in previous columns, a MCU typically senses digital signals such as switch inputs that are either on or off. A MCU can also sense analog signals by using an Analog-to-Digital Converter (ADC) to change the analog signal to digital. PWM is a way to take a digital output and vary the on — or high time — to create a variable output. If the PWM signal runs at a fixed frequency, then changing the high time of the signal will change the low time of the signal, as well. The amount of time the signal is high is called the pulse width. The period of the signal is defined as the time from one rising edge to the next rising edge of the square wave signal and is inversely proportional to the PWM frequency. The period can easily be calculated by using the formula period = 1/frequency. A 1 kHz frequency will give us a 1 millisecond period.

■ FIGURE 1. Low pass filter.



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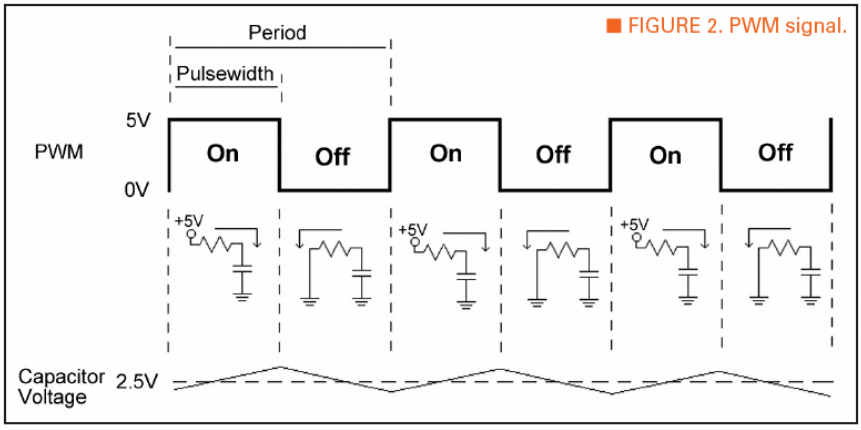
Duty cycle is what we are really interested in when using PWM to control a circuit. Duty cycle is the amount of time the signal is high, relative to the period of the PWM signal. Duty cycle is measured in percentage of the whole period. For example, a 50% duty cycle will be high for half the period and low for half the period. If we wanted to create a different duty cycle — such as a 20% duty cycle — then we would make the pulse width last only 20% of the period.

Using PWM gets very interesting because there are many applications for it. Simplest of all and a great place to start is driving some kind of low-pass filter. By driving a simple resistor-capacitor low-pass filter circuit (see Figure 1) directly from the MCU's PWM port, the variable pulse width will be averaged out by the capacitor's charge and discharge rate through the resistor. Figure 2 shows this in detail, using a 50% duty cycle.

The top part of Figure 2 shows the square wave generated by the MCU. In a digital world, the high pulse can be considered on and the low pulse considered off. The circuit diagrams below the pulses show what the low-pass filter is doing. The arrow shows the direction of the current. The bottom portion of the figure shows the charging and discharging voltage of the capacitor. This depends upon the frequency of the signal, and the values you select for the resistor and capacitor. The important thing to notice is the dashed line running through the charge/discharge signal. That dashed line is the average voltage across the capacitor. Even though the MCU is outputting five- or zero-volt signals only, you would see about 2.5 volts across the capacitor if you measured it with a voltmeter.

■ FIGURE 2. PWM signal.



APPLICATIONS

PWM is used in many

common applications. If the PWM signal were connected to an LED circuit, the brightness of the LED could be changed by controlling the PWM signal's duty cycle. However, this is where the design techniques get tricky. The speed at which the human eye can detect light plays a factor. Therefore, you must match the frequency of your PWM signal to what you want the LED to look like. If you drive the LED on and off too quickly using the PWM signal, then the LED will look like it never turned on. If you drive it too slowly, then all you will see is a blinking light. The trick is to get the frequency right and then adjust the duty cycle. If you get this set up properly, then you can control the brightness of the LED by just varying the duty cycle in whatever increments you want. I'm sure you have seen applications where an LED is controlled this way. A typical one is lighting in an automobile. If you turn the dimmer knob, you can change how bright or how dim the instrumentation panel backlighting is. Most vehicles use PWM to control the brightness of LEDs or even light bulbs behind the displays. A light bulb's brightness can also be controlled by this method (see Figure 3).

Motor control is another application for PWM. By controlling the ground circuit of a motor with a transistor driven by a PWM signal (see Figure 3), you can control the motor's speed. This is another tricky design that requires you to match the frequency of the PWM signal to the motor characteristics, but this is very efficient.

CREATING A PWM SIGNAL

So, how do you create a PWM signal with a Microchip PIC? It turns out to be very easy, and you have multiple options for doing so. As usual, I focus on the beginner in this column, and microEngineering Labs' PICBASIC PRO compiler is my choice for creating the PIC software. The sample version (which limits you to 31 commands) will once again be enough to create a PWM example. If all you want to do is create a PWM signal, then the code snippet included here will get the job done. (See Listing 1.)

The software simply drives PORTC pin 5 high and then delays 20 milliseconds. The software then drives PORTC pin 5 low and delays 80 milliseconds. The GOTO command makes this a continuous loop. The results are shown in Figure 4. I captured the signal on a digital scope and then cut a section of the picture to show only the waveform. I then added the time measurement cursors, based upon the scope settings. The grid is at 25 milliseconds per division. The period is actually slightly more than 100 milliseconds, because of the time required to execute the HIGH, LOW, and GOTO commands, but these are minor. As you can see, the short snippet of code produced a 20% duty cycle signal at 10 Hz.

LISTING 1: Simple PWM.

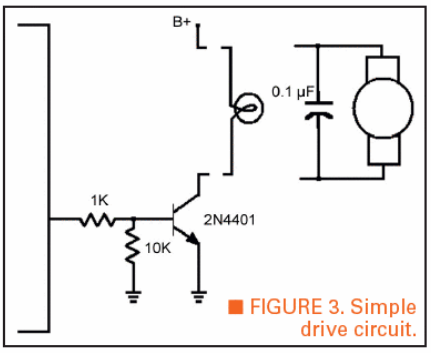
```
TRISC.5 = 0      ' Set PORTC bit5 to Output

Main:
High PORTC.5     ' Set PORTC bit5 high
Pause 20         ' delay for 20 msec
Low PORTC.5      ' Set PORTC bit5 low
Pause 80         ' delay for 80 msec
Goto main        ' loop back to main label
```

PICKIT 2 LOGIC TOOL

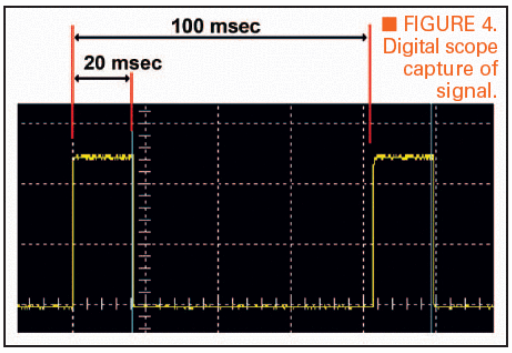
For years, I did work like this without an oscilloscope. Much of my work was by trial and error, until I finally was able to purchase a low-cost digital scope. Oscilloscopes have come down in price as electronics have become less expensive, but I have an even lower-cost option for you — Microchip's PICkit 2 programmer. That's correct, I said the PICkit 2 programmer, which I've suggested in previous articles for following along with this column. The PICkit 2 tool is a great development programmer for PIC MCUs, and now I have another reason to suggest you use it. In fact, I have two additional reasons.

Back in my November '07 column, I showed how to use the built-in UART Tool to capture data and send it to Excel. That was one reason. The PICkit 2 designers added another great tool called the Logic Tool to the interface software that runs on your PC. The Logic Tool is a simple three-channel logic analyzer. A logic analyzer is similar to an oscilloscope, except that it just shows logic-level square wave signals. Since that is what we are working with here, I thought I would introduce this great feature. Figure 5 shows the same waveform as Figure 4, only as captured on the PICkit 2 Logic Tool. (Figure 10 shows a picture of the actual hardware, with dual programmers in action.)

The MPLAB IDE software has also been updated to allow you to work with multiple PICkit 2 tools. The Logic and UART Tools are entered through the PICkit 2's



■ FIGURE 3. Simple drive circuit.



■ FIGURE 4. Digital scope capture of signal.

standalone software. This means you might have multiple programmers connected to your computer's USB ports, along with the MPLAB IDE, and the PICkit 2 stand-alone applications all running simultaneously; so this could cause confusion on which tool is being used by the MPLAB IDE and which one is used by the GUI standalone application. When you open the stand-alone software, the screen will ask which PICkit 2 you want to use, as seen on the right side of Figure 6. I have two PICkit 2s connected to my PC. Notice also in Figure 6 that they have unique names. You can give each PICkit 2 a unique name through the "Calibrate VDD and Set Unit ID..." selection under the Tools menu. This is the same menu where you select the UART or Logic Tool. This Unit ID name will then get stored in the internal PICkit 2 memory so it will stay with the unit. I also put a small piece of tape with the number on the programmers case, so that I can keep them straight.

To use multiple PICkit 2s with the MPLAB IDE, you need to update to the MPLAB software version 8.15, which was recently released. You may also have to download the latest control software, depending upon how old your current version is. The MPLAB IDE will ask you which PICkit 2 it should work with. That window is also shown on the left in Figure 6. Therefore, I can easily have three PICkit 2s for many projects. One is used for programming and debugging from the MPLAB IDE, one for UART communication, and one for a logic analyzer. You can buy three of these for far less than the cost of an oscilloscope. If you need to monitor more than three signals, then you can use even more of them in Logic Tool mode.

The Logic Tool has cursors built in, so you can measure the pulse width. As you can see in Figure 5, the X cursor is blue and the Y cursor is purple. You use the left mouse button to set the X position and the right mouse button to set the Y position. The screen shows the time difference between them. The time measurement in Figure 5 is the pulse width of our PWM signal, which measures 20.8 milliseconds — not 20, as the PAUSE command created. The extra 0.8 is from the delay in the HIGH and LOW commands. I used Channel 3 on the PICkit 2 connector and the trigger was set to a rising edge on Channel 3 in the Trigger portion of the Logic Tool window. The red trigger line shows that the signal was actually captured on the rising edge. As you may have noticed, the Logic Tool is a great addition to the PICkit 2.

HARDWARE PWM

Now, back to the PWM explanation. Driving a PWM signal is easy, but most of the time you'll want to do other things in your program, in addition to creating a PWM signal. As soon as you try to do something else, you will be affecting the signal timing. This is why many PIC MCUs have a hardware PWM built in. Some have more than one. The hardware PWM runs on its own in the background once it is set up, allowing you to write code to run separately in your main loop. You can modify the setup for a particular duty cycle or frequency in your main loop, but the hardware PWM will continue running even when your main loop is running a PAUSE command or some other delay section of code.

The PIC16F690 included with Microchip's PICkit 2 Starter Package has a hardware PWM port on-chip. It's called the ECCP or Enhanced Capture Compare PWM. The datasheet has a detailed explanation but, based upon reader feedback, the datasheets tend to confuse the beginner. I'll try to simplify it here. Figure 7 shows the key diagrams I captured from the datasheet to help me explain the hardware PWM setup.

The block in Figure 7 labeled FIGURE 11-3 is the block diagram of the hardware PWM circuitry. Though the details are small, you can hopefully see that the operation is based on the TMR2 (or Timer 2) within the PIC16F690 MCU. I added the block labeled FIGURE 7-1 because this shows a key component left off of the PWM block diagram — the TMR2 prescaler. This divides the oscillator down, prior to feeding Timer 2 with its heartbeat.

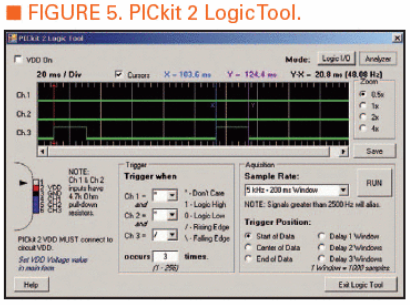
The block labeled FIGURE 11-4 shows the definition of the PWM output. You can see the diagram definitions are similar to Figure 2, described earlier. The details to note in this block are the equations for the end of the pulse width and the end of the period. When the TMR2 value equals the PR2 register value, the signal starts over. Therefore, the PR2 value determines the frequency of the PWM signal. The block labeled EQUATION 11-1 shows the formula for calculating the PWM period. It's a straightforward equation:

PWM Period = (PR2 + 1) * 4 * Tosc * (TMR2 Prescale Value)

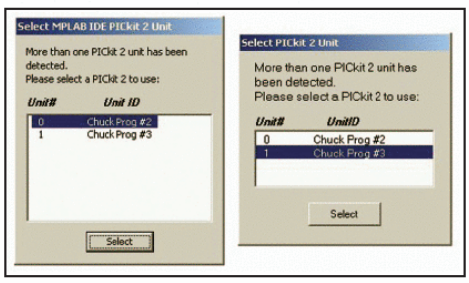
SETTING THE PWM FREQUENCY

Tosc is the period of the oscillator you are using to run the PIC16F690 MCU. Tosc is equal to 1/Fosc, where Fosc is the oscillator frequency at which the PIC is running. PWM period is also 1/PWM frequency. You will typically know the frequency you want, but not the period. Therefore, reworking the formula to solve for PR2 is more useful:

■ FIGURE 5. PICkit 2 LogicTool.



■ FIGURE 6. PICkit 2 selector windows.



PR2 = [(Fosc) / (4 * TMR2 Prescale * PWM Frequency)] - 1

If you use the internal oscillator set to its default Fosc = 4 MHz, and use a TMR2 prescaler of 1:4, and want a PWM with a frequency of 1 kHz, then PR2 is calculated to be 249:

PR2 = [4MHz / (4 * 4 * 1 kHz)] – 1 = 249

If the number calculates to a value larger than 255, we would have to adjust the prescaler to a larger value or change the oscillator speed. The Timer 2 prescaler is set in the T2CON register and you only have three selections, so you may have to change your oscillator to get the PWM frequency you need. Once you have the PR2 value, you will use that in the next step.

SETTING THE DUTY CYCLE

The duty cycle is controlled by setting bits in two different registers. This is because the duty cycle is capable of 10-bit resolution or 1,024 different settings. Since the PIC16F690 is an eight-bit MCU, we need two registers to store the value. The CCPR1L holds eight bits and the CCP1CON register has the extra two. Figure 8 shows the bit settings.

The reworked formula for the duty cycle is:

CCPR1L:CCP1CON = 4 * (PR2 +1) * Duty Cycle Ratio

Since we already calculated PR2 as 249, and assuming we want a 20% duty cycle, then we get the answer:

CCPR1L:CCP1CON = 4 * (249 +1) * 0.2 = 200

A 200 in binary is 0011001000 so the CCPR1L register gets the most significant eight bits 00110010 and the CCPCON1 register bits are set to match the final two bits, which are zero.

SAMPLE PROGRAM

If you look through the sample programs that come with PICBASIC PRO, you will see a hardware PWM sample program that shows all these values being set in the PICBASIC PRO program. That program is shown in Listing 2. You can see that the PR2 value and the duty cycle registers are set up just the way we calculated here.

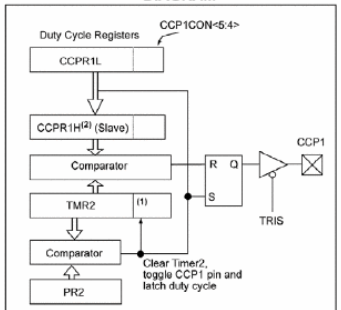
In addition to these calculations, the program in Listing 2 makes PORTC bit 5 an output, then controls the Timer 2 prescaler, and sets the ECCP hardware to run in PWM mode with the command lines below:

```
TRISC.5 = 0             ' Set PORTC.5 (CCP1) to output
CCP1CON = %00001100     ' Set CCP1 to PWM
T2CON = %00000101       ' Turn on TMR2, Presc=4
```

HPWM COMMAND

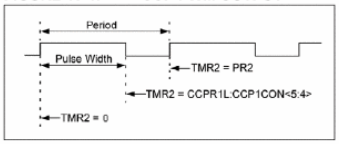
These steps were probably tough to understand for the true beginner. I went through all of this so you know the fundamentals of how to control the PWM hardware in PICs. PICBASIC PRO makes this so much easier than the sample program demonstrates, which is one of the reasons I call PICBASIC PRO the perfect compiler for the beginner. PICBASIC PRO takes all these set up steps and

FIGURE 11-3: SIMPLIFIED PWM BLOCK DIAGRAM



Note 1: The 8-bit timer TMR2 register is concatenated with the 2-bit internal system clock (Fosc), or 2 bits of the prescaler, to create the 10-bit time base.
2: In PWM mode, CCPR1H is a read-only register.

FIGURE 11-4: CCP PWM OUTPUT



EQUATION 11-1: PWM PERIOD

$$PWM\ Period = [(PR2) + 1] \cdot 4 \cdot TOSC \cdot (TMR2\ Prescale\ Value)$$

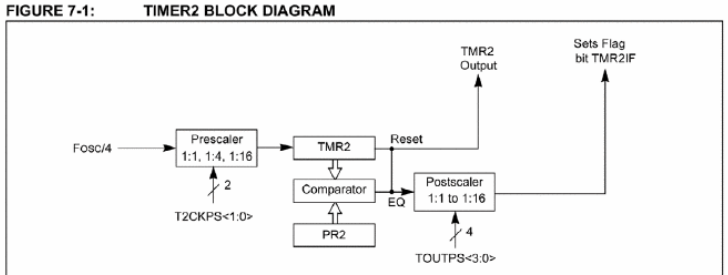
EQUATION 11-2: PULSE WIDTH

$$Pulse\ Width = (CCPR1L:CCP1CON<5:4>) \cdot TOSC \cdot (TMR2\ Prescale\ Value)$$

EQUATION 11-3: DUTY CYCLE RATIO

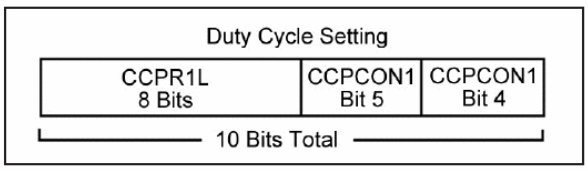
$$Duty\ Cycle\ Ratio = \frac{(CCPR1L:CCP1CON<5:4>)}{4(PR2 + 1)}$$

FIGURE 7-1: TIMER2 BLOCK DIAGRAM



■ FIGURE 7. PIC16F690 datasheet PWM details.

■ FIGURE 8. Duty cycle settings registers.



LISTING 2: Hardware PWM sample program.

```
duty            VAR     WORD            ' Duty cycle value (CCPR1L:CCP1CON<5:4>)


                        TRISC.5 = 0             ' Set PORTC.5 (CCP1) to output
                        CCP1CON = %00001100     ' Set CCP1 to PWM
                        T2CON = %00000101       ' Turn on Timer2, Prescale=4

' Use formula to determine PR2 value for a 1KHz signal,
' 4MHz clock, and prescale=4. (4E6/(4*4*1E3))-1=249

                        PR2 = 249               ' Set PR2 to get 1KHz out

' Use formula to determine CCPR1L:CCP1CON<5:4> value for
' ends of range 20% to 80%.  (249+1)*4*0.2=200 (20% value)
' (249+1)*4*0.8=800 (80% value)


                        duty = 200              ' Set duty cycle to 20%

loop:           CCP1CON.4 = duty.0              ' Store duty to registers as
                CCP1CON.5 = duty.1              ' a 10-bit word
                CCPR1L = DUTY >> 2

                duty = duty + 10                ' Increase duty cycle

' Since the total sweep of duty is 600 (800-200) and
' we are adding 10 for each loop, that results in 60
' steps min to max. 1 second divided by 60 = 16.67mS

                        Pause 17                ' Pause 1/60 of second

                        IF (duty < 800) Then loop  ' Do it again unless 80% duty cycle

                        duty = 200              ' Reset to 20% duty cycle

                        GoTo loop               ' Do it forever
```

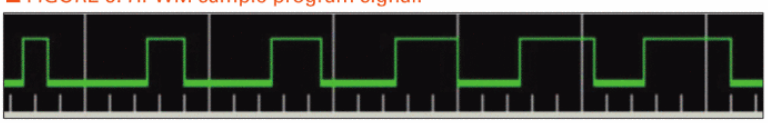
reduces them down to a couple of DEFINE statements and a single command called "HPWM."

The command line is:

HPWM Channel, Dutycycle, Frequency

Channel specifies which hardware PWM channel to use.

■ FIGURE 9. HPWM sample program signal.



LISTING 3: HPWM example program.

```
duty            VAR     WORD            ' Duty cycle value (CCPR1L:CCP1CON<5:4>)

DEFINE          CCP1_REG PORTC          ' HPWM 1 Pin Port
DEFINE          CCP1_BIT 5              ' HPWM 1 Pin Bit

' HPWM Channel,Dutycycle,Frequency
'
' Channel - specifies which hardware PWM channel to use.
'
' Dutycycle - specifies the on/off (high/low) ratio of the signal. It ranges
' from 0 to 255, where 0 is off (low all the time) and 255 is on (high) all the
' time. A value of 127 gives a 50% duty cycle (square wave).
'
' Frequency - is the desired frequency of the PWM signal.
'
' Use formula to determine values to sweep Duty Cycle
' from 20% to 80%. 2 0 = 0%, 255 = 100%.
' 20% * 255 = 51, 80% * 255 = 204
```

continued ...

Dutycycle specifies the on/off (high/low) ratio of the signal.

Frequency is the desired frequency of the PWM signal.

Now, one drawback is that you lose a little of the duty cycle's 10-bit resolution because PICBASIC PRO gives you an eight-bit value to work with. A value of 255 is 100% duty cycle and a value of 0 is 0%. Therefore, a 20% duty cycle would equal 51 (0.20 * 255 = 51).

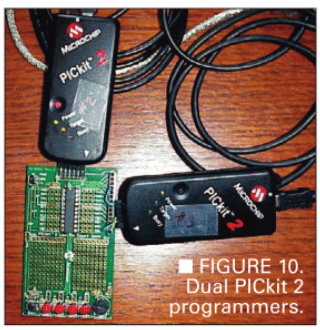
The program in Listing 3 shows the simplified HPWM version. The DEFINE statements select the port and pin of the ECCP pin. The PIC16F690 hardware PWM pin is called the CCP1 pin, and it's located at PORTC bit 5. The duty cycle is initially set to 51, but the program will increase it after a delay to make the duty cycle change in a continuous loop. The frequency is set to 1,000 in the HPWM command, making the frequency fixed at 1 kHz.

The waveform created by this example was captured with the Logic Tool (see Figure 9). You can see the pulse width change. I actually increased the value of the variable "duty" to create increments of 10%, not just the value 10 shown in the sample program to get this waveform close-up.

The hardware for this article is shown in Figure 10. I used a few short pieces of wire to connect the PICkit 2 Logic Tool to the demo board's expansion header, which has a Vdd, Vss, and CCP1 pin connection.

CONCLUSION

I hope this short description



■ FIGURE 10. Dual PICkit 2 programmers.

of how to control the hardware PWM on the PIC16F690 will help you create some interesting projects. I'm sure you will see PWM examples everywhere, now that you have a better understanding of the PWM. I have a Mac mini computer on my desk that has a white LED to indicate that power is on. While the mini is working, the LED slowly gets brighter and then dimmer, kind of like the pulse of a heartbeat. It is controlled by a PWM signal.

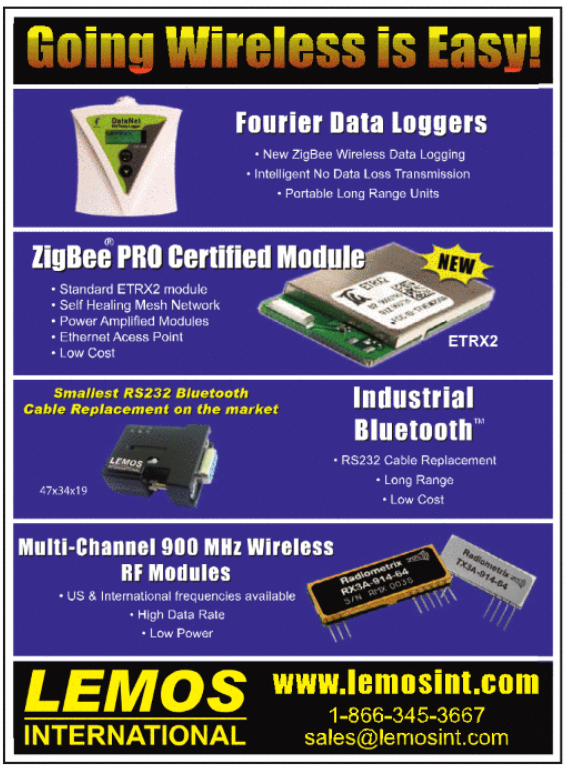
Listing 3 continued ...

```
                        duty = 51               ' Set duty cycle to 20%
loop:
                        HPWM 1, duty, 1000      ' Channel 1, start at 20% duty
                                                ' and 1Khz frequency
                        duty = duty + 10        ' Increase duty cycle
' Since the total sweep of duty is 600 (800-200) and
' we are adding 10 for each loop, that results in 60
' steps min to max. 1 second divided by 60 = 16.67mS
                        Pause 17                ' Pause 1/60 of second
                        IF (duty < 800) Then loop ' Do it again unless 80% duty cycle
                        duty = 51               ' Reset to 20% duty cycle
                        GoTo loop               ' Do it forever
```

The PICkit 2 has once again come through for us in this series, and I'm convinced it's the best beginner development tool. I like it so much that I used it for all the projects in my latest book *Beginner's Guide to Embedded C Programming*. You can get that book from the *Nuts & Volts* bookstore (**www.nutsvolts.com**).

Adding the Logic Tool to the PICkit 2 software is a great feature for beginners and students, or even for schools who can't afford a scope for every student. Figure 10 shows how easy it is to add a logic analyzer to any project with just a few wire connections. Even projects that don't have an MCU, such as a 555 timer circuit, could be used with the Logic Tool. I would still use an eight-pin PIC instead of a 555, but you get my point.

I hope I succeeded in covering everything, but I need your feedback to let me know. Please send your comments to chuck@elproducts.com. I try to read them all, though I know that a few get trapped in the spam folder. Reference "N&V" in the subject line so I can easily identify your email. See you in November. **NV**



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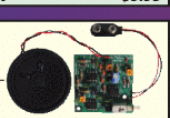

Not only does it chirp just like a real cricket, it also senses temperature and changes the chirp accordingly. Can actually determine temp by chirps! Squishing under your feet voids warranty! Runs on 9VDC battery. Speaker included.

ECS1 **Cricket Sensor Kit** **$24.95**

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SA7 **RF Preamp Kit** **$19.95**

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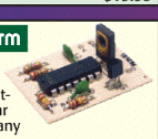
TS1 **Touch Switch Kit** **$9.95**

Walking Electronic Bug

Built around a pair of subminiature cell phone motors, this bug wanders around looking for things to bump into! Sensors below his LED eyes sense proximity and make him turn away! Steer him with flashlights too! Runs on two "N" batteries.

WEB1 **Walking Bug Kit** **$29.95**

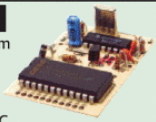
Mad Blaster Warble Alarm



If you need to simply get attention, the "Mad Blaster" is the answer, producing a LOUD ear shattering raucous racket! Super for car and home alarms as well. Drives any speaker. Runs on 9-12VDC.

MB1 **Mad Blaster Warble Alarm Kit** **$9.95**

DTMF Encoder Decoder



Decodes standard Touch Tones from telephones, radio, or any audio source. Detects and decodes any single digit and provides a closure to ground up to 20mA. Great for remote tone control Runs on 5VDC.

TT7 **DTMF Encode/Decode Kit** **$24.95**

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MK132 **Cable Polarity Checker** **$8.95**

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MK108 **Water Sensor Alarm Kit** **$7.95**

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RFS1 **RF Actuated Relay Kit** **$19.95**

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Add time delay power-off to any of your projects or circuits! Momentary push button selects desired time delay (1H, 2H, 4H, 8H, 24H) and LED flashes faster as time approaches. On-board 10A relay. Runs on 120/240VAC.

K8075 **Power Saver Timer Kit** **$24.95**

IR Remote Control Checker

Is your IR remote control working? Just point and shoot, and this kit will let you know! Confirms IR signal generation from any IR remote and displays proper receipt on the four LED display. Don't change the batteries, check the remote first! Runs on a standard 9V battery.

MK137 **IR Remote Checker Kit** **$7.95**

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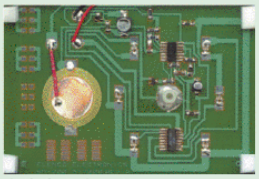

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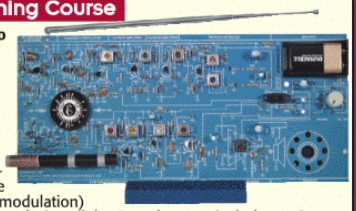

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- ✓ Power Transformers

■ WITH RUSSELL KINCAID

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions.

Send all questions and comments to:
Q&A@nutsvolts.com

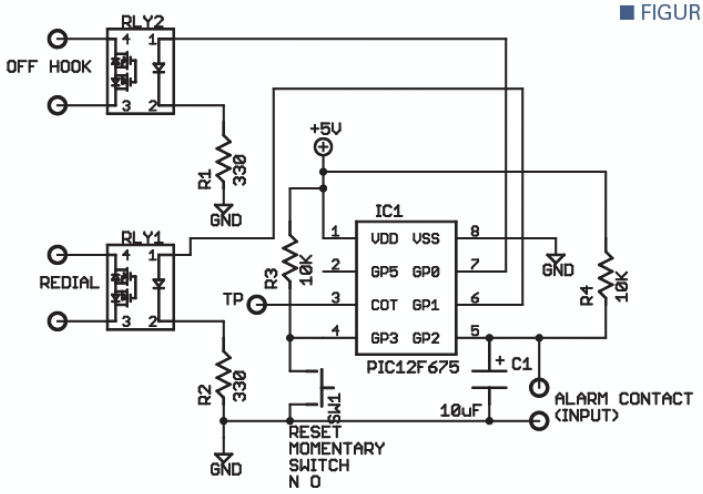
MULTIMETER BUZZER FREQUENCY

Q I need to change the audio frequency of the continuity buzzer function of a DVM890 multimeter. The audible frequency of the buzzer is beyond my hearing range. Having it operate at the standard frequency of 1,000 Hz would be great. Of course, the ideal circuit would be 1,000 Hz at 0 dB into 600 ohms.

— James P. Brendage

A The usual buzzer operates at the resonant frequency of the piezo speaker which is 3 kHz. I have the same problem when checking continuity so I hang the meter on my shoulder near my ear. I checked a defunct meter to see how the buzzer was done. The circuit was using a 4093 quad 2 input nand Schmitt-trigger oscillator. I couldn't make that work, so I opened my Masteck meter (I figured, I can't hear it anyway, so what do I have to lose?). This circuit used an LM358 and a transistor, but there was only one 220 pF capacitor in the vicinity, so I increased it to 680 pF. The piezo speaker is undoubtedly less efficient at 1,000 Hz, but I could hear it much better. My recommendation is: open your meter, find the capacitor (it will be in the range of 100 to 1,000 pF), and make it three times larger.

■ FIGURE 1



PARTS LIST (MOUSER PART NUMBERS)

PART	PART NUMBER	PRICE
RLY1, RLY2	762-LH1540T	2.30
IC1	579-PIC12F675-I/P	1.85
R1, R2	271-330-RC	0.90/10
R3, R4	271-10K-RC	0.90/10
SW1	506-MPS103F04	0.98
C1	140-MLRH16V10-RC	0.29

ALARM AUTO DIALER

Q I would like to interface my alarm system with a phone that has a quick-dial button to call my cell phone. If I receive a call from my home phone and I am not home, I know the alarm has been activated. The alarm has relay contacts that will close for the duration of the alarm (about 15 minutes).

I would like a circuit that takes the contact closure as input and provides two outputs: one to take the phone off-hook and one to activate the redial. There should be a slight delay between going off-hook and redial, and the phone should stay off-hook for several seconds. After the system has timed out, it should not respond to the alarm until reset.

I realize I can buy an auto dialer but I have the phone and this seems like an interesting project that others may appreciate.

— Al Catan

A The simplest circuit would be a microprocessor and two solid-state relays, but programming the micro is not simple, so I would rather use discrete logic. However, after looking at the complexity of the problem, I decided that the micro is the only reasonable way to go.

Hacking the phone could be difficult if it is a newer one with capacitive matrix switches, but if it is an older one with actual switches, this approach will work.

The circuit is Figure 1; the program is Figure 2. On power-up, the program goes around the NOGO loop until an alarm pulls pin 5 low, then the program jumps to the START loop. The phone goes off-hook and 100 ms later the redial button is pushed. The phone stays off-hook, letting the cell phone ring, for two seconds and then hangs up. The micro goes to sleep, the clock stops, and it remains in this condition until the reset button is pushed.

I found that the micro was starting up in a strange mode that could not be reset. I experimented and found that C1 would make it start up in alarm mode and then reset would work. I don't know why that happens, but it works.

As usual, I can send you a programmed PIC12F675 for $5 if you want to build the circuit.

```
'*****************************************************************
'*  Name    : alarm timer.bas                                    *
'*  Author  : Russ Kincaid                                       *
'*  Date    : 6/2/2008                                           *
'*  Version : 1.0                                                *
'*  Notes   :Switch closure at the alarm starts the program      *
'*           :running.  The off hook relay is energized immed-   *
'*           :iatly and the redial relay is energized 100 mS     *
'*           :later. The off hook relay is deenergized after two *
'*           :seconds.                                           *
'*****************************************************************
    REM DEVICE = 12F675
    REM CONFIGURATION: INTOSC CLOCKOUT, WDT DISABLED, PWRUP TIMER ENABLED,
    REM                MCLR FUNCTION: RESET, BROWNOUT RESET: ENABLED.
    CMCON = 7                   'SETS DIGITAL MODE
    ANSEL = 0                   'GPIO.0 TO GPIO.3 SET AS DIGITAL
    TRISIO = %00001100          'GPIO.3 (PIN 4)AND INTERRUPT (PIN 5)AS INPUT
    VRCON.7 = 0                 'TURN OFF VOLTAGE REFERENCE
    DEFINE OSCCAL_1K 1          'TO SAVE OSCILLATOR CALIBRATION
'    ***************************************************************
NOGO:

      IF GPIO.2 = 0 THEN START      'If alarm contact closes

      GOTO NOGO                     'WAIT FOR ALARM

START:

      HIGH GPIO.0             'PIN 7 HIGH, ENERGIZE OFF HOOK RELAY
      PAUSE 100               '100mS
      HIGH GPIO.1             'PIN 6 HIGH, ENERGIZE REDIAL RELAY
      PAUSE 100               '100mS
      LOW GPIO.1              'REDIAL IS ONLY MOMENTARY
      PAUSE 2000              'WAIT 2 SECONDS
      LOW GPIO.0              'HANG UP
      SLEEP 1                 'SINCE WDT IS DISABLED, NEVER WAKES
      END                     '(until reset)
```

FIGURE 2

SIX VOLT TO 12 VOLT CONVERTER

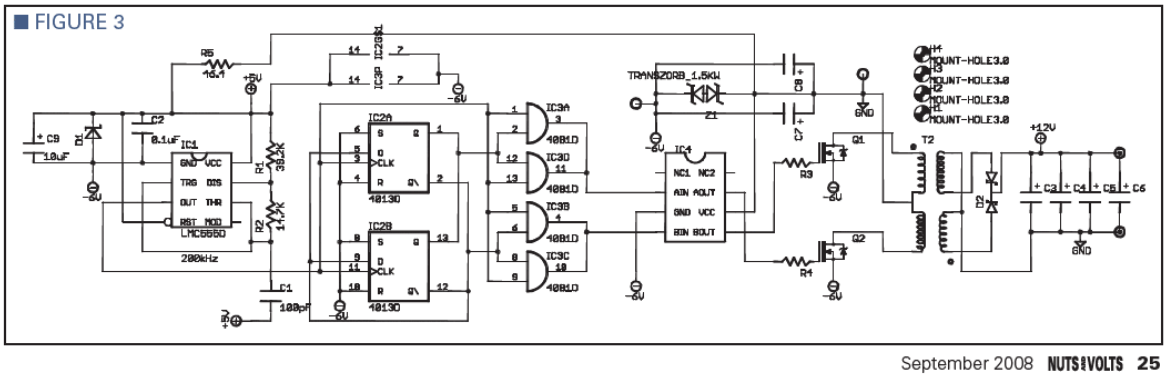
Q I'm a vintage car buff and am currently restoring a '41 Plymouth. The car has a six volt positive ground electrical system and I would like to install a nice AM/FM CD player for my road trips. I need a circuit for a 6V positive ground to 12 volt negative ground switching power supply that is beefy enough to power a nice audio system. Any thoughts?

— Doug

A This could be done with a boost circuit, but somehow I think using stored energy in a magnetic field would not be as efficient as a straight transformer, as in the old vibrator supplies. The circuit of Figure 3 uses a 2:1 transformer operating at 100 kHz. The usual radio fuse in an automobile is 10 amps, so that is what this supply is designed to provide. If you want more power than that, I don't want you in my vicinity.

In the circuit (Figure 3), the 555 runs at 200 kHz and is divided by 2 in IC2. The two halves of IC2 are connected in parallel because that is just as easy as leaving one unused. The 555 trigger pulse is fed to IC3 in order to have dead time between switching one power transistor on

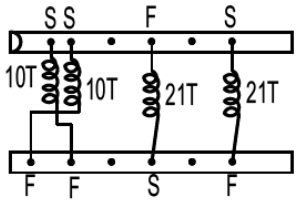
FIGURE 3



and switching the other off. IC4 is a FET driver; it can supply a lot of urrent for a short time, which is what is needed to charge the input capacitance of the FET. R3 and R4 limit the peak current that IC4 has to supply. The FET is rated 100 volts and 22 amps so it is well within its rating, even though the input current will exceed 20 amps under full load, because each one is on 50% of the time.

For the transformer, I used a 12 pin bobbin that was on hand. I tried a smaller one but could not get enough turns on it. I tried to wind #16 wire but that was impossible so I used four #27 wires in parallel. Using parallel wires is an advantage because the current runs on the surface and multiple wires provide greater surface area. The transformer layout is Figure 4. By starting on pin 1 and finishing on pin 11, and starting on 2 and finishing on 12, I can run power straight across from 2 to 11 for the center-tap, leaving 1 and 12 for the transistor drain connections. On the secondary, winding from pin 9 to 4 then 6 to 7 allows me to jumper 4 and 6 for the center-tap, which simplifies the layout. The bobbin is Magnetics #PC-B3515-L1 and the core is Magnetics #OF43515EC.

A big problem when operating in an automotive environment is protecting the circuit from transients which can reach 60 volts when starting, or when the battery is disconnected while running. I have not tried the transzorb approach before but if it works as advertised, the peak voltage should be limited to 15 volts. The output has multiple filter caps to handle the ripple current and to reduce the ripple voltage. Figure 5 is the parts list.



6 to 12 volt xfmr, bottom view
12 June 2008
Each winding consists of 4 #27 wires in parallel.

■ FIGURE 4

RELAY DRIVER

Q I need a circuit to key a five volt SPDT relay using the external speaker output from a GMRS radio. Once keyed, it needs to remain keyed as long as a signal is being received. Use transistor or op-amp circuits if possible.

— Rileys Electronics

A This circuit (Figure 6) will work as long as the input signal is one volt peak or more, but don't exceed five volts without a reverse diode to ground at the NPN base. The turn-off time is about 1/2 second, but you can increase C1 for longer time. You can substitute another MOSFET but it must have a logic level rating. I did not put a diode across the relay because it turns off slowly and the 100 volt rating of the MOSFET is unlikely to be exceeded. The Mouser part number for the MTP10N10EL is 863-MTP10N10ELG and the 0.33 µF cap is 581-BQ024D0334K (**www.mouser.com**).

POWER TRANSFORMERS

Q What I lack now is information on the physics of constructing my own power transformers. Do you know of an outlet to purchase components to make a power transformer, i.e. the core, bobbin, and magnet wire? Also, what is the deal on toroidal transformers? Any information on constructing those? Notes on what gauges of wire produce what voltages would be helpful also.

— Tyre Daniely

A Designing a transformer is a very complex undertaking. I don't know how to do it even though I have built some transformers that worked. I will try to provide some foundation and you can study catalogs from Magnetics, Inc., and Micrometals, Inc. (**www.mag-inc.com** and **www.micrometals.com**). That being said, it is more cost-effective to buy a power transformer than to build one; mainly because there is no source for small quantities of the core or bobbin. Most manufacturers will give you a sample if you want to build one anyway. I have taken a laminated core transformer apart to rewind it, but that is a pain that I prefer not to repeat. Enameled magnet wire is available from any electronics supplier (Mouser and Allied, for example).

Whenever a current flows, a magnetic field is produced around the conductor. The magnetic field increases as the current increases and, as the magnetic field increases, it generates a voltage in the conductor that opposes the force voltage. This conforms to Newton's third law: For

SIX TO 12 VOLT CONVERTER PARTS LIST

■ FIGURE 5

PART	DESCRIPTION	MOUSER P/N
■ IC1	555 Timer, CMOS	511-TS555IN
■ IC2	4013 Dual D Flip/Flop	595-CD4013BME4
■ IC3	4081 Quad 4 Input AND	595-CD4081BE
■ IC4	MC34152 FET Driver (SMD)	863-MC34152PG
■ Q1, Q2	N-FET, 60V, 22A, TO-220	512-FQPF30N06L
■ D1	Zener, 5V, 1/4W, 1N751	512-1N751ATR
■ D2	Schottkey, Dual, 100V, 12A (SMD)	844-12CWQ10FNPBF
■ Z1	Tranzorb, 10V, 1.5 kW	625-1.5KE10CA-E3/54
■ C1	100 pF, 50V, 5%, NPO	140-50NS-101J-RC
■ C2	.1 µF, 50V, X7R	140-CC502B104K-RC
■ C3-C8	270 µF, 16V, Electrolytic	75-94SP277X0016FBP
■ C9	10 µF, 16V, Tantalum (SMD)	80-T494B106K016
■ R1	39.2K, 1/4W, 1%	271-39.2K-RC
■ R2	14.7K, 1/4W, 1%	271-14.7K-RC
■ R3, R4	5 ohms, 1/4W, 5%	291-5.1-RC
■ R5	47 ohms, 1/4W, 5%	291-47-RC

every action, there is an equal and opposite reaction. When the conductor (wire) is wound into a coil, the effect is magnified and the device is called an inductor. The ability to produce a magnetic field is called inductance.

A transformer is created when two inductors share a common magnetic field. The magnetic field lines of the primary inductor cut through the winding of the secondary inductor and induce a voltage. If a load is connected to the secondary, a current will flow. The current will be limited by the resistance and reactance of the circuit; furthermore, the wire must be large enough to carry the expected current.

The reactance of the primary must be high enough that it does not overheat the wire due to the inductive current, which does no actual work. This will normally fix the number of turns of the primary. The coupling between primary and secondary is not perfect, but close enough that you can use the equation:

$$Vp/Np = Vs/Ns$$

In words: The voltage ratio will be directly proportional to the turns ratio. The primary current will be inversely proportional to the turns ratio: Ip = Is*Np/Ns + In, where In is the inductive current that flows all the time.

The ability of a material (iron) to support a magnetic field is nonlinear and approaches saturation at some flux density. The transformer designer must select a core of sufficient cross-sectional area that the density is below saturation. A given core can be rated in its power handling capacity in volt-amperes. If you want a transformer to supply six volts at 10 amps, that is 60 VA, plus add some for core losses. That's about it. Study the catalogs and you CAN wind your own transformer.

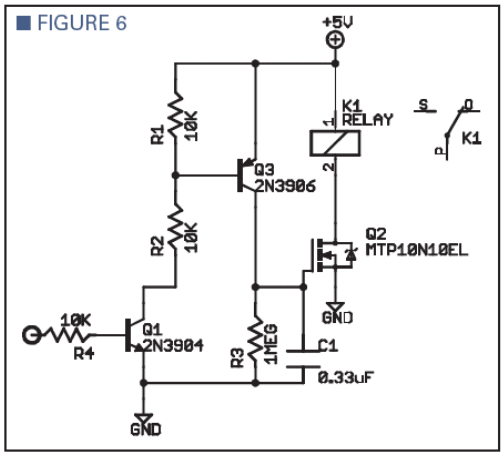
The toroid is just a different shape; it supposedly has less magnetic flux outside the core than other shapes, but there is no bobbin so winding it is a pain and not worth the trouble, in my opinion. Much better to use a pot core which has many of the advantages of the toroid and has a bobbin.

WIRELESS TV CONVERTER

Q When TV goes completely digital next year, I would like to know if I can obtain an analog transmitter for the house that will take the analog output from a new digital-to-analog TV converter and transmit it on the present Channel 3 frequency for all of the "old" analog TVs in the house. That way, one converter box could serve several TVs without a wired connection. Where can I obtain such an animal? Will the "old" Channel 3 be sold for some other use? Would some other frequency be better?

— Glenn Winkler

■ FIGURE 6



A The HDTV converter box will have an RF output on Channel 3 or 4. You can connect it to an antenna to transmit to other receivers which have a receiving antenna. The level will be low enough that you don't have to worry about FCC regulations. I recommend a folded dipole

MAILBAG

Dear Russell,

I have a question regarding your answer to "Voltage Reduction" in the July issue, where you give us a nice schematic for a PWM regulator to handle Richard's one amp load. I would have turned to National Semiconductor's LM2576 "Simple Switcher" voltage regulator IC for a solution that would easily handle a couple amps, and with a drastically reduced parts count. Is there, however, some inherent advantage to your more complex circuit design; a cleaner output, or less RFI generated perhaps?

Judy May, W1ORO
Union, KY

Response: There are advantages to my circuit. The FET switch has lower loss than the Darlington bipolar switch in the LM2576 and I wanted to run at 100 kHz but the LM2576 is fixed at 52 kHz. The reason I used the more complex circuit is that I had done it already, so did not go looking for a more elegant solution. When designing one off, minimum parts count is not the primary consideration. There should not be any difference in ripple output or RFI in the two designs.

Dear Russell,

I have a question regarding the Digital Radio and TV question in the June 2008 issue where it was said "can handle up to three digital TV signals." I'm not sure what the real limit is — I'm too lazy to look at the standards, but empirically I know it's at least four. Am I hallucinating or had I noticed you live in Milford, NH...? If so, WGBX has Channels 44.1, 44.2, 44.3, and 44.4. PAX similarly has four subchannels on 68 (those are the virtual channels, of course).

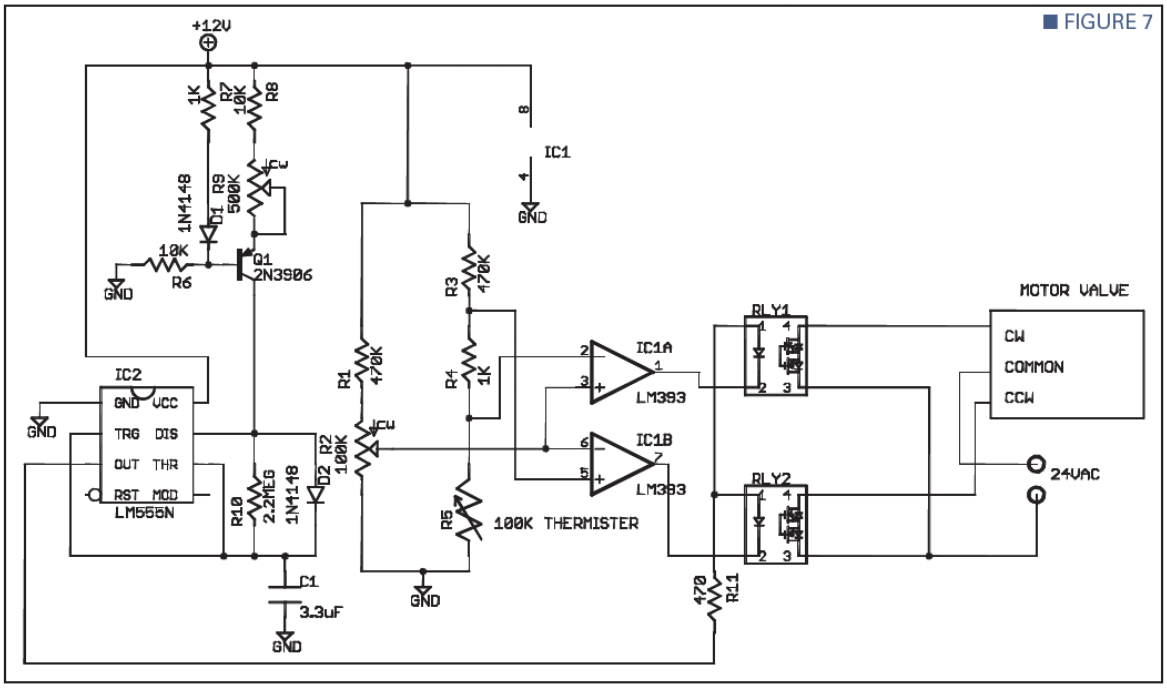
"... think of it in terms of time division multiplex ..."

I'm not so sure that I see the connection. I do, however, think I could explain it to you if you want. Since we're neighbors, why not give me a call or if you want, you could stop by and see HDTV in action and we could chat about it.

Ken Lesniak

Response: Thanks for the info, Ken. I may take you up on that offer when I am not up to my eyeballs in alligators.

■ FIGURE 7

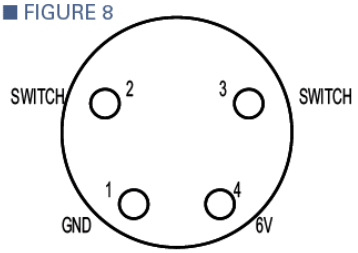


antenna, tuned to Channel 3 (or 4). Locate the antenna so that the receiving antennas are broadside to it.

The antenna can be made from 300 ohm TV lead-in: Cut a section seven feet, 4-1/2 inches, and bare 1/2 inch of wire on each end; twist them together and solder. The overall length should be 7', 3-1/2". Find the center and cut one of the wires. Bare enough wire that you can solder to another piece of 300 ohm twin lead which will be the lead-in to the transmitter or receiver.

If your TV has two screws for connecting the RF input, it is 300 ohms and you don't need a transformer, but if the input (or output of the converter) is an F connecter, it is 75 ohms and you need to use a 75 ohm to 300 ohm transformer. These have been commonly available but may become obsolete. All the channels will still be there, but in digital format.

■ FIGURE 8



VIBRATOR PINOUT

VIBRATOR REPLACEMENT

Q I am restoring a 1951 Chevy six volt radio that has a vibrator in the power section. Do you have a circuit that would replace the vibrator using a couple of transistors or something? I have the radio working by using an external power supply and am now refinishing the case after removing the rust. I hope you can help me.

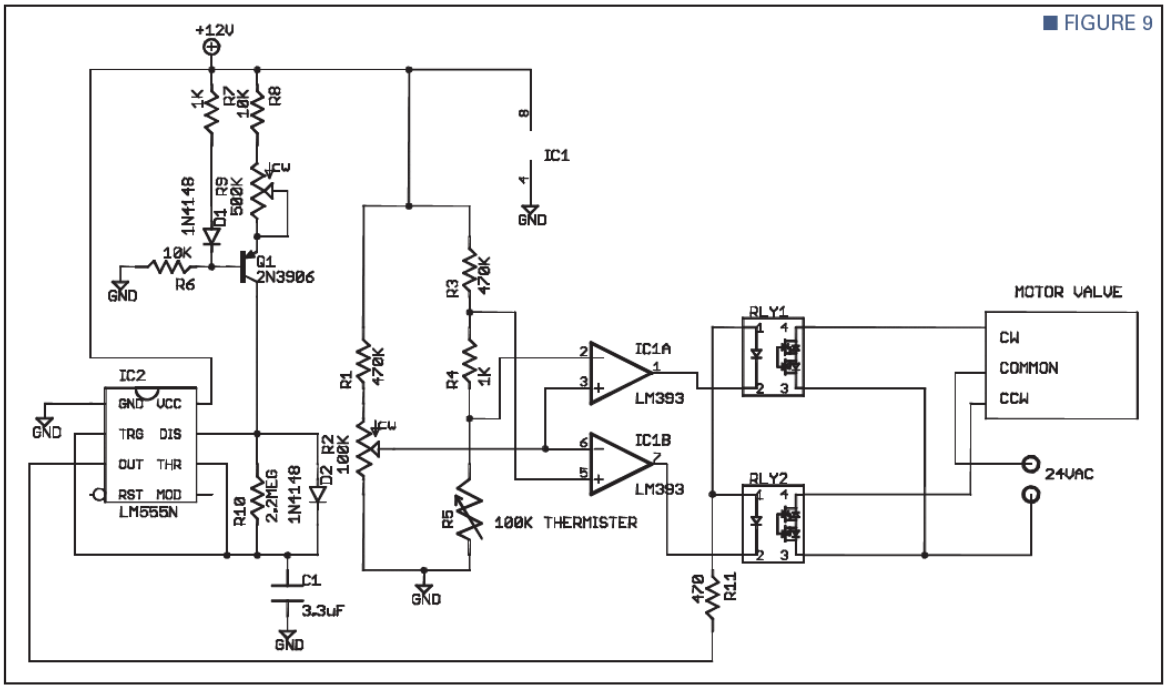
— Dave

A The six volt vibrator operated at a low frequency, so I will design for 100 Hz. I downloaded the schematic from: **www.nostalgiaair.org/resources/835/m0001835.htm**. If you have the old vibrator, you could remove the guts and plug in this circuit (Figure 7) per Figure 8. There aren't any single IC solutions that operate on six volts, so a discrete IC circuit is needed. It happens that the circuit of Figure 3 is just what is needed; I just have to change the 555 frequency to 200 Hz (R1=69.8K, R2=1.47K, C1=0.1 µF) and you can use the parts list of Figure 5. You may also want to replace the 6X4 rectifier with two 1N4007 diodes.

TEMPERATURE CONTROL CIRCUIT

Q Commercial controllers for home heating system water mixing valves are very expensive and because they are developed as a "one design fits all" application, they usually have far more features than are necessary. I need a simple control to maintain the output water temperature of a mixing valve by commanding the actuating motor to rotate the mixing valve either CW or CCW as required to change the mixing proportions of the incoming hot and warm water. The

■ FIGURE 9



temperature (75-180° F) can be easily monitored by strapping a sensor on to the outlet water copper pipe. The required temperature setting could be as simple as a potentiometer with experimentation and an external mechanical thermometer for determining the proper setting. The actuating motor is 24 VAC and rotates quite slowly, and is probably best interfaced by a contact closure. The system temperature as a whole also responds quite slowly, so the temperature sampling rate could be quite infrequent. An override input to force the valve to full open (or close) would also be quite convenient. Can you please suggest a starting point for an experimental circuit? Can this be easily accomplished PIC-less?

— Tim Bates

A In Figure 9, Q1 is an adjustable constant current source charging C1 through D2. The 555 output will be high, allowing the motor to run during the charge time. The range of charge time is very short to five seconds. The discharge time (motor not running) is fixed at five seconds by R10. The resistance of the thermistor is 100K at 25° C (about 77° F) and 12K at 80° C (about 176° F). The corresponding set voltages at R2 will be 2.1 VDC and 0.3 VDC. When the water temperature is higher than the set temperature, the resistance of the thermistor is low, pulling pin 5 of IC1B low and turning on RLY2. When the water temperature is lower, the resistance of the thermistor is high, allowing pin 2 of IC1A to go high, turning on RLY1. You may want to swap the connection to the motor valve, depending on your configuration. The G3VM-41GR5 solid-state relay is rated 300 mA max; if your motor valve requires more current, other relays are available, such as Mouser 849-CPC1979J, rated 600 VAC, 3A. The parts list is Figure 10.

You will want to adjust the on and off times of the motor such that the temperature stabilizes quickly but does not oscillate around the set temperature. There is a dead time (hysteresis) determined by R4 of about 1° F where the motor is not turning CW or CCW. **NV**

TEMPERATURE CONTROL PARTS LIST

■ FIGURE 10

PART	DESCRIPTION	MOUSER P/N
■ IC1	Dual comparator	512-LM393N
■ IC2	555 timer	512-LM555CN
■ Q1	PNP, 60V, 100 ma	512-2N3906TFR
■ D1, D2	Gen-purp. diode, 50V 10 ma	512-1N4148T26A
■ RLY1, RLY2	Solid-state relay, 40V, 300 ma	653-G3VM-41GR5
■ C1	3.3 µF, 50V, film	871-B32529D5335K189
■ R1, R3	470K, 1/4W, 5%	271-470K-RC
■ R2	100K potientometer, linear	317-2090F-100K
■ R4, R7	1K, 1/4W, 5%	271-1K-RC
■ R5	Thermistor, 100K	871-B57560G104F
■ R6, R8	10K, 1/4W, 5%	271-10K-RC
■ R9	500K potientometer, linear	317-2090F-500K
■ R10	2.2M, 1/4W, 5%	271-2.2M-RC
■ R11	470 ohm, 1/4W, 5%	271-470-RC

NEW PRODUCTS

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TELESCOPE CAMERAS
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The Imaging Source, an international manufacturer of imaging hardware and software for astronomy, is now offering amateur astro-photographers a series of highly affordable, low noise telescope cameras to capture high quality images of the night sky.

The telescope cameras ship in blue and black anodized aluminium and zinc housing, measure 50 mm x 56 mm, and weigh only 260 g. The included nose piece is mounted onto a C/CS mount on the front of the telescope camera. On the rear, a USB 2.0 or FireWire connector is available (model specific). A threaded tripod adapter on the bottom rounds off the exterior of the telescope camera.

Monochrome and color types are available with and without an IR cut filter in three resolutions: 640x480, 1024x768, and 1280x960. The cameras deploy low noise CCD chips from Sony, which have an exposure time of up to 60 minutes and a maximum frame rate of up to 60 fps.

The telescope cameras ship with the camera control and acquisition software "IC Capture.AS," which allows image sequences and singular images to be saved to disk. Furthermore, using the highly intuitive graphical user interface, all camera parameters, such as exposure, sensitivity, and frame rate can be set.

In the British magazine *Astronomy Now*, Nick Howes wrote:

"The Imaging Source have delivered cameras and software that offer the serious Solar System imager a product which will deliver outstanding results for years to come."

Similarly, in the American magazine *Sky & Telescope*, Sean Walker wrote:

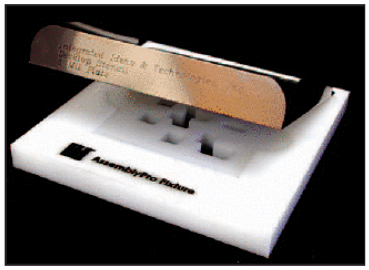
"The Imaging Source [CCD imager] is a well-designed, versatile camera that is a natural progression for planetary astro-photographers looking to upgrade from a consumer webcam. The camera control software IC Capture.AS seems to be a mature program itself, complementing the camera perfectly."

The telescope cameras are available worldwide and start at only USD $350 or EUR 290.00 (without shipping and sales tax). They can be purchased online and from an international network of dealers. To learn more about The Imaging Source telescope cameras, download "IC Capture.AS" and see hundreds of sample images. Take a look at the websites listed below.

For more information, contact:
The Imaging Source
Web: **www.AstronomyCameras.com** or **www.AstronomyCamerasBLOG.com**

PROTOTYPE TOOL
FOR DOUBLE-SIDED SURFACE-MOUNT ASSEMBLIES

Integrated Ideas & Technologies, Inc., has announced a new prototype assembly tool that allows



manufacturers to assemble double-sided surface-mount assemblies right at their desk.

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For more information, contact:
Integrated Ideas & Technologies, Inc.
Web: **www.integratedideas.com**

CAN A COMPUTER TRAVEL BACK IN TIME?

Multilabs has just released its latest product, a computer called "Retro." With its built-in Basic language interpreter and minimal operating system, the eight-bit micro-computer has been reborn into

continued on page 32

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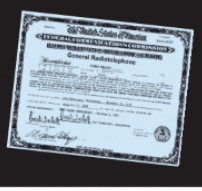

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continued from page 30

today's world. It certainly isn't a computer as they are known today. But instead, as its name suggests, Retro is a throw-back to the early days of computing a Basic language computer. "I miss being able to turn on a computer, have it boot in about one second, and then start writing programs," says Don Bartley, the owner of Multilabs. "It was also nice having direct control over the system before complex operating systems took over." From this, Retro was born. Retro brings back the earlier days of computing. A computer with a built-in Basic language interpreter, commands to give the user direct control over the system, no complex operating system to get in the users way, and even an expansion port that allows users to connect their own equipment to it and write programs to control them.

"It may seem a bit simplistic in today's world but Retro has many uses and applications," says Don, "There is something for everybody, beginners to experts alike." Retro offers an environment that is not overwhelming and is user friendly that a beginner can learn computer programming on. More seasoned programmers will enjoy the direct control over the system without a complex operating system getting in the way. "Besides programming, Retro offers its expansion port," says Don, "With the expansion port, any user can connect their own devices and equipment to Retro and program Retro to control them." "Retro combine's software and hardware disciplines together," Don adds. The expansion port goes beyond this use and can be used in commercial and industrial applications, as well. With the expansion port, Retro can control external equipment such as relays, motors, solenoids, and other industrial equipment. What's more is that the expansion port is two-way so it can also read data from temperature and position sensors, for example. With this level of control, Retro is not just for the home user but has a wide array of applications.

Retro's other connectors are for a PS/2 style keyboard, digital joystick, asynchronous serial communications, sound, and a VGA monitor. Retro comes with built-in non-volatile memory storage for user programs so programs can be stored for later use. It also sports an expansion socket so users can add-on program storage and even transfer programs between Retro computers. At a starting price that doesn't 'break the bank,' Retro is affordable to a wide array of users. "Whether for personal or professional use, Retro is affordable, easy to use, and above all enjoyable," says Don. Can a computer travel back in time? Yes it can.

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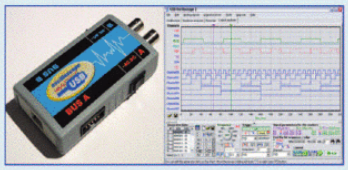

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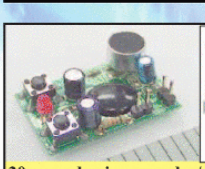

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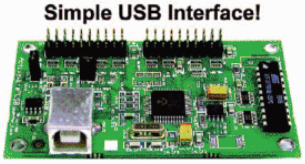

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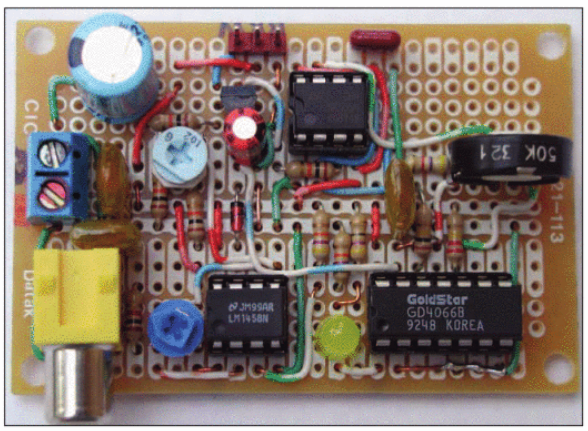
THE TALKING SKULL KIT

BY VERN GRANER

BOO! Fall is in the air and Halloween is just around the corner. It's time to start getting ready for those trick or treaters that will be coming to your door in just a few short weeks! Halloween is a fun time for make-believe and for kids (and adults!) to play "dress up." It's a time to make fun of the things that scare us and to have fun being scared. It's also a time where folks who have a bit of tech-savvy can impress the heck out of their neighbors.

An evening at the workbench spent crafting a new creation can result in laughter and screams from the neighborhood kiddos. "How did you DO that!?" is a phrase we all love to hear when someone gets a close-up look at something we've built. Soldering back together a broken battery connector or wiring up a boat trailer for the neighbor can only gain you so much credibility. If you want the "Joneses" to have to keep up with you this Halloween, an LED-eye blinking, servo-operated, animated talking skull may be just the ticket!



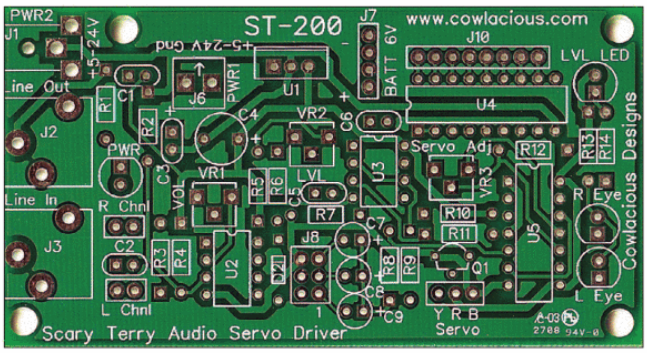
You May Ask Yourself, "How Did We Get Here?"

A carved pumpkin or a spooky scarecrow on the front porch is pretty typical fare for Halloween. But taking it to the next level requires a bit of skill and imagination. Enter Terry Simmons (a.k.a., "Scary Terry") of California State Polytechnic University, Pomona, CA. An avid "haunter" and electronics buff, Terry wanted to animate a life-sized plastic "Bucky" skull he had purchased. When he went looking for a way to accomplish this, he discovered that many of the motion systems for talking or animated props were pretty complicated. Some required a microcontroller or computer and expected you to invest hours of painstaking programming to coordinate all the servo motions to the sound track. Wanting something simpler, he decided to build a sound-activated circuit to drive a typical hobby servo motor. On his website, he describes the project:

"My goal in creating this was for a relatively simple, inexpensive, and reliable circuit that doesn't require programming a microcontroller for each individual movement. I've used several of these circuits over the last several Halloweens to provide mouth movements on Bucky

■ FIGURE 1. Prototype of Scary Terry audio servo board. (Photo courtesy of Terry Simmons.)

■ FIGURE 2. Cowlacious ST-200b version of the audio servo board.



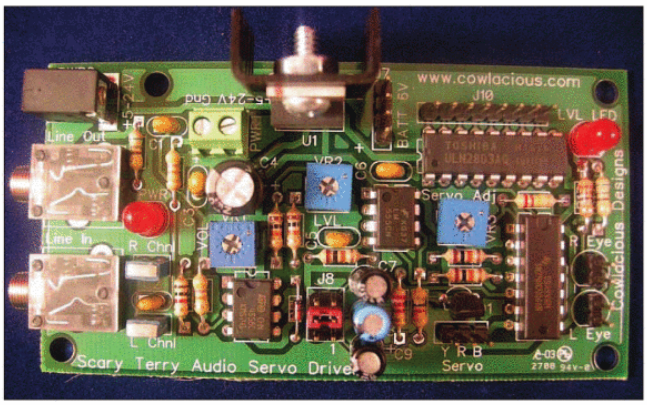
skulls and other animatronic heads. They have been a very reliable addition to my haunt."

The result was "Scary Terry's Audio Servo Driver." This small board detects any incoming audio signal and moves a servo motor to animate the jaw or mouth of a prop. This way, no programming is needed and you can change the sound track for the prop at any time.

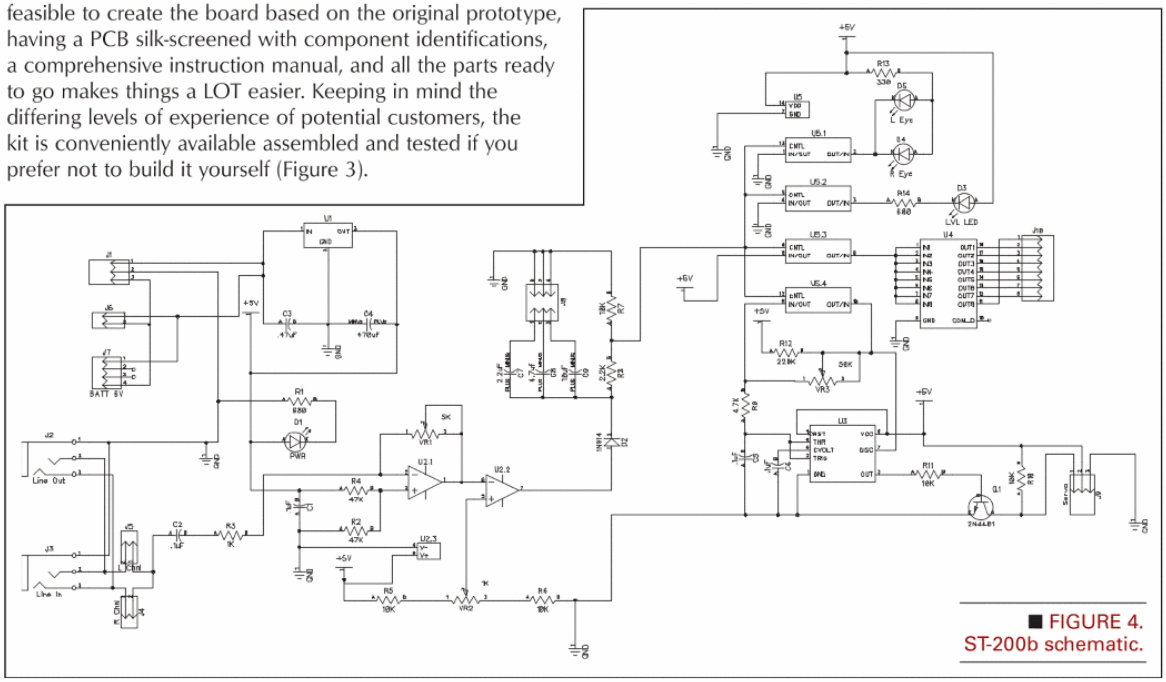
Terry made the schematics, parts list, and proto board circuit layouts available on his page (Figure 1) and even published detailed information on the circuit theory of operation. However, many folks found the creation of the circuit a bit too complicated or time consuming. Though the circuit was perfect for many haunter's needs, it really needed to be simplified and documented (i.e., "kitted") in order to make it more accessible to less electronically advanced folks.

Cowlacious to the Rescue!

As an electronics technician by trade, Carl Cowley (of Cowlacious Designs) was in the right place at the right time to create a kit around Terry's circuit. With Terry's permission and assistance, Carl took the original schematic design and laid out a number of different printed circuit board (PCB) revisions. He finally settled on the "ST-200b" version that was streamlined and made more versatile (Figure 2). Though it is still quite feasible to create the board based on the original prototype, having a PCB silk-screened with component identifications, a comprehensive instruction manual, and all the parts ready to go makes things a LOT easier. Keeping in mind the differing levels of experience of potential customers, the kit is conveniently available assembled and tested if you prefer not to build it yourself (Figure 3).



■ FIGURE 3. Cowlacious ST-200b fully assembled.



■ FIGURE 4. ST-200b schematic.

How it Works, Theoretically Speaking

To best use the audio servo board, it is important to explore the underlying theory of operation. Basically, the board works by detecting the presence or absence of sound. When sound is detected, the board instructs the servo motor to move from its "home" position towards a "target" position. When sound is absent, the servo is instructed to move back to the home position. When the servo motor is coupled to a jaw or mouth, the motions are surprisingly accurate.

If you have a look at the schematic (Figure 4), we can go over the operation in detail so we can really understand the parts and how they work. The audio signal enters through the 1/8" stereo jack J3. Jack J2 is wired in parallel so that the signal can exit the board to an external speaker system. J4 and J5 control which channel is passed to the next stage (i.e., left, right, or both).

The audio signal from J4/J5 passes through C2 and R3 which provide some isolation and the resulting signal is fed to the U2.1 op-amp which is configured as an audio amplifier. VR1 is used to adjust the input gain of the op-amp section to match the incoming audio signal level.

The output of the first op-amp is then fed to the second op-amp which is configured as a comparator. VR2 is used to set the threshold that triggers the comparator output. Jumper J8 is used to select which damping capacitor (C7, C8, or C9) is used to shape the decay of the trigger signal that feeds the U5 quad switch. Larger capacitance results in slower, smoother movement; smaller capacitance results in faster motion. When the audio signal is above the threshold of the comparator, the output of the comparator is passed to all four inputs of the U5 quad switch. U5 is then used to drive four separate outputs.

The first output (U5.1) drives a pair of remotely-mounted LED eyes that light up when sound is present. The second output (U5.2) drives an LED that is used as a guide to help you visually calibrate the board to the incoming audio level (i.e., it lights when the board is detecting audio). The third output (U5.3) is used to drive the ULN2803a driver and the fourth output (U5.4) is used to control the 555 timer.

The 555 timer is configured as an astable multivibrator and when the trigger level changes, U5.4 changes the timing resistor which shifts the PWM width from ~0.3 ms to ~3.7 ms (VR3 adjusts the 3.7 ms down to 2.0 ms or so allowing you to position the servo's home position). The PWM output is inverted and driven to the servo jack by R11 and transistor Q1.

The ULN2803a is used as a high-current driver allowing you to control devices such as incandescent lamps, small motors, relays, or solenoids. Though the ULN2803a has built-in back-EMF diodes, if you plan to drive some larger solenoids it might be a good idea to place an additional back-EMF protection diode in the circuit. The ULN2803a is a neat addition to the original prototype board and comes in handy if you decide you would prefer to have the audio servo board drive a solenoid valve connected to a pneumatic cylinder. This way, you could use the board to control the movement of very large puppet jaws or mouths weighing tens or even hundreds of pounds!

To assist in getting the best performance out of the circuit, the board has a series of adjustments that allow you to adapt the device to the sound track you choose. For example, you can choose which channel (left, right, or both) is used to drive the servo motor. This is important since the servo will respond to any sound it detects. Typically, you would want to use a separate channel for dialog and sound effects. Or, you can daisy-chain the devices together and have each talking skull respond to a different dialog track. This allows you to have a pair of skulls carry on a conversation! You can also use the J4/J5 jumpers to select which board should respond. The J8 jumper block is used to fine tune how responsive you want the jaw to be.

The Head Bone's Connected to the Servo Bone

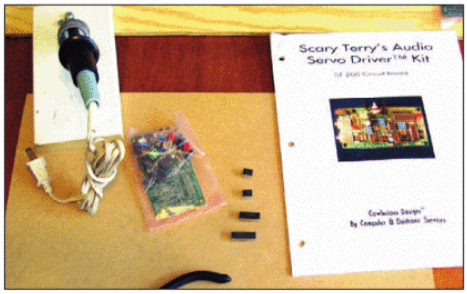
Okay, so enough theory. Let's get to the application! As a member of the TXfx group in Austin, TX, I thought it would be fun to have a "Make and Take" with talking skulls. I sent out an email message announcing the idea to all my scary friends on the TXfx mailing list.

For those of you not familiar with the concept, a "Make and Take" is part work-day and part party-day. Folks with common interests and overlapping skill sets gather at a predetermined time and place to take on the same challenge. We meet up (usually on a weekend) and by cooperating and teaching each other, we each make a working device

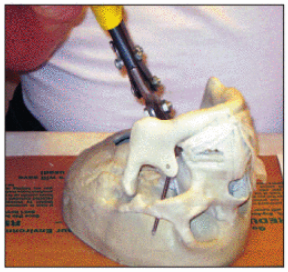
■ FIGURE 5. TXfx members working at the skull assembly area.

■ FIGURE 6. TXfx members and folks from The Robot Group at the soldering area.

■ FIGURE 7. Eric Lundquist and Vern Graner (cleverly disguised as a giant pumpkin) at the system test area.



■ FIGURE 8. The Cowlacious ST-200b kit and color manual.



■ FIGURE 9. Tin snips used to remove a small part that blocks the mounting bracket.

■ FIGURE 10. Rotary tool used to smooth out the servo bracket mounting spot.

to take home. Of course, having some experts on hand (i.e., my buddies from The Robot Group) certainly doesn't hurt since they can help troubleshoot any issues that arise. A Make and Take is a lot of fun and is very effective in both learning new things and getting things done.

After my announcement on the mailing list, I counted up the RSVPs and it looked like we had about 10 folks from all around central Texas that wanted to make talking skulls, with some folks signing up to build a pair! To meet the demand (and to make sure I had one for myself), I ordered 12 complete Cowlacious Talking Skull kits with red LED eyes. (Note: See the Resources section to order a kit for yourself in time for Halloween!)

The weekend of the Make and Take arrived and we set up the center island in my kitchen as the "skull prep" area (Figure 5). The kitchen table was set up with three soldering stations for circuit board assembly (Figure 6). We also had some speakers and a small MP3 player for testing the finished units (Figure 7).

I opened the kits and was happy to see that each one was bundled with a full-color multi-page instruction guide (Figure 8). If you'd like to have a look, the instruction books are available directly from Cowlacious (see Resources) as PDF documents. The booklet had detailed instructions and photographs on how to modify the fourth class Bucky skull to hold the servo motor and allow a piece of piano wire to reach the jaw. There were also detailed step-by-step instructions on how to assemble the audio servo board in a separate color booklet. As you can see in the photos, we were all using these guides constantly as we went along and they were VERY helpful!

Though the skull modification guide is very detailed, the actual modification is fairly simple and can be recapped in short order: A small piece of plastic is "snipped" away from the bottom of the skull to make room for the servo bracket mounting screw (Figure 9). A rotary tool is used to smooth an area inside the skull for the servo bracket (Figure 10). The springs that hold the jaw to the skull are removed, then holes are drilled in the skull to allow clear plastic wire ties to act as hinges for the jaw (Figure 11). The servo bracket is attached to the skull with a nut and bolt (Figure 12) and then a hole is drilled to allow the piece of stiff wire (i.e., piano wire) to be threaded from the servo down to the jaw (Figure 13). Finish by attaching the servo horn to the servo (Figure 14) and you have a modified skull ready to go (Figure 15).

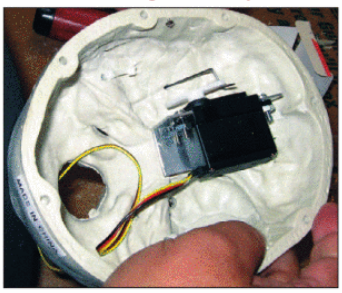
Smoke Test!

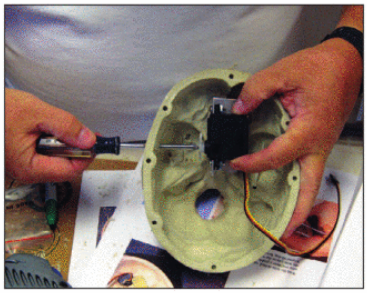
While some folks were busy modifying the skulls, the soldering area was in full swing (Figure 16). The first board was completed by Paul Atkinson (Figure 17) and we took it to the test area to try it out. We powered it up and uh, oh, the servo refused to budge! After a bit of head scratching, connection testing, and taking readings on the board using a meter and an oscilloscope (Figure 18), we found that two pads on the circuit board had a solder bridge. Once that was fixed, the board worked fine.

■ FIGURE 11. Zip ties used to create a hinge for the jaw.

■ FIGURE 12. Attaching the servo bracket to the skull.

■ FIGURE 13. Piano wire push-rod threaded through hole to jaw.





■ FIGURE 14. Tightening the servo horn on the servo.

■ FIGURE 15. Steven Reeves shows off his completed skull modification.

■ FIGURE 16. TXfx and Robot Group members soldering together printed circuit boards.

I then headed to the garage and got some additional lighting for the solder table. Lesson learned – good lighting is critical when working with small electronics! We tested each board as it was completed and with the exception of an inverted LED and a couple of other small solder mistakes, we were able to get a 100% success rate even on boards assembled by folks that had very little soldering experience.

Let's Give Them Something to Talk About!

So, now that we have a talking skull, we need something for it to say! To help get you started, there are some pre-made spooky and silly MP3 files with dialog and music/efx on separate channels available for download from the *Nuts & Volts* website (**www.nutsvolts.com**). These sound files can be loaded into an MP3 player or burned to an audio CD for use with the project. There are some corny jokes and some scary sounding haunted house rules, as well as other bits of dialog that can be fun to play through the skull. If you load all of them onto a player and then set it to random-play mode, your talking skull can chatter away through the evening with interesting and ever-changing fun dialog. Some folks like to use a pair of skulls and set one to respond to the left side audio and one to respond to the right side audio. They then hide a speaker behind or under each skull and play some back and forth dialog usually referred to as "Joking Skellies." This way, the two skulls carry on a conversation with each one responding to its own unique sound track.

Special Thank Yous

■ "Scary" Terry Simmons for his very cool servo audio board design and his generosity in sharing the design with all of us.

■ Carl Cowley of Cowlacious Designs for creating the Talking Skull kit and getting the kits sent to us in time for the Make and Take.

■ The TxFX members who came out and made the Make and Take so much fun.

■ Paul Atkinson of The Robot Group for being our #1 soldering guru.

■ Eric Lundquist of The Robot Group for troubleshooting, teaching, and testing.

■ Ed Gonzalez of The Robot Group for photography and tech assistance.

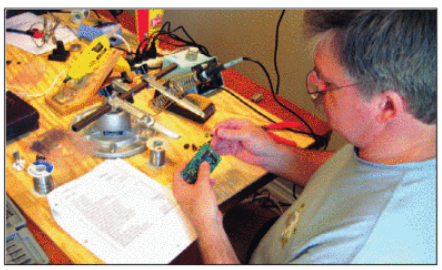
■ Hedstrom Music for some of the cool MP3 sound files!

■ And, last but not least, to my wife Kym for allowing us to wreck her kitchen for the weekend! Thanks Honey!

It is Remotely Possible

If downloading MP3s or burning CDs isn't to your liking, as an alternative you could use a standard FM radio to drive the audio servo board and an FM transmitter to make the talking skull say anything you like! Imagine placing the skull on the front porch and watching from your window as people approach. What? You don't have an FM transmitter? Well, as luck would have it, there's an FM transmitter kit featured in this month's issue of *Nuts & Volts* that is also available as a kit in the *Nuts & Volts* store. To learn about this cool kit, turn to page 40.

■ FIGURE 17. Paul Atkinson finishing the first ST-200b board.



■ FIGURE 18. Paul Atkinson uses an oscilloscope to troubleshoot the first board.

■ FIGURE 19. ST-200b kit mounted inside an animatronic "talking" Christmas present.

Applications

The talking skull is not only a fun item to have around, but the kit itself contains portions that should be interesting to many different hobbyists as it requires drilling, sanding, soldering, wiring, audio, and even a bit of robotics. Using the controls on the board, you should be able to adjust the skull to provide a very realistic sync with all kinds of different audio source. My daughter likes to put various pop-music CDs in the player and watch the skull sing with the voice of stars like Britney Spears or Hannah Montana. To see some videos of the finished talking skulls from our Make and Take, check out Resources for links.

Alternate Uses

If the audio servo kit is intriguing but seems like a one trick pony (or maybe you're just not into Halloween), remember that there are lots of other uses for this board. Instead of buying the skull kit, you could purchase just the board and servo motor for use in animating other props or puppets. The board is well suited to making a talking Santa Claus, a group of singing elves, a wise-cracking easter bunny, or a chatty Christmas present (Figure 19). It can be used anywhere you want to move an object in relation to an audio source.

Conclusion

That about wraps it up for this project. If you have any questions or if you would like to share your thoughts on the Talking Skull Kit, please stop by the *Nuts & Volts* forums where you can discuss projects, share pictures and videos, or get ideas from other builders. As always, if you have any questions or comments, feel free to send them to me at vern@txis.com. **NV**

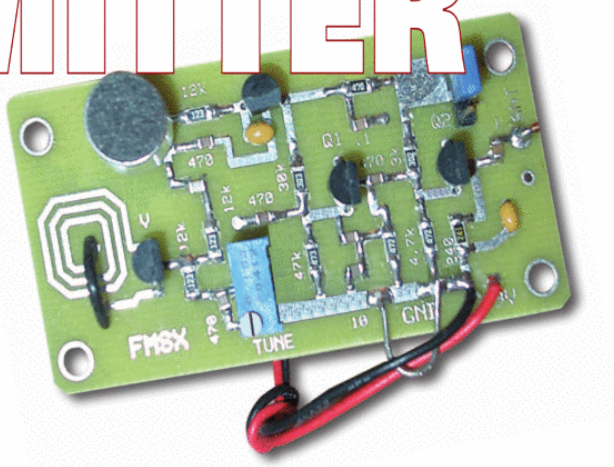
Resources

- Scary Terry's web page **www.scary-terry.com**
- The Robot Group **www.TheRobotGroup.org**
- Cowlacious Designs kit manuals **www.cowlacious.com/Support.htm**
- Videos of the Talking Skull system in action: **www.cowlacious.com/Scary_Terry_Vids.htm**
- TXFx group **http://groups.yahoo.com/group/TXfx/**
- Video from the Make and Take **www.youtube.com/user/VernGraner**
- *Nuts & Volts* Webstore **http://store.nutsvolts.com**
- Haunted MP3 files courtesy of Hedstrom Music: **www.hedstrom.net**

Just in time for Halloween! The Talking Skull kit is available NOW in the *Nuts & Volts* online store! Visit **http://store.nutsvolts.com** to order yours today!

USE SURFACE-MOUNT DEVICES TO BUILD AN FM TRANSMITTER

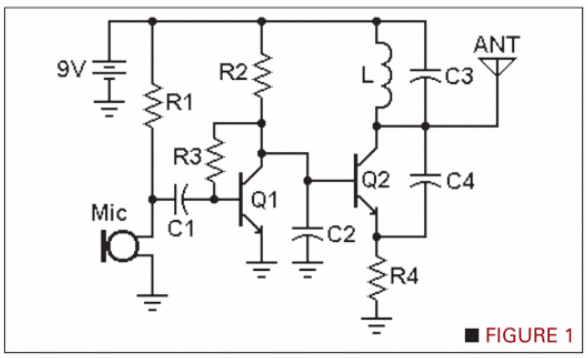
BY JIM STEWART



In this article, we will construct a low-power FM transmitter that can be received with a standard FM radio. Along the way, we will look at how varactor diodes work and how to use an inductor that's in the circuit board.

Though I've built many projects over the years, I have to confess that I've never used surface-mount devices (SMD). Those little parts just had me intimidated. I thought soldering them would be a nightmare. It seems like now all the really neat new parts coming out are SMD only, so the time had come for me to face my fear. This FM transmitter is my first attempt at using SMD and, as it turned out, soldering wasn't that bad once I figured out the trick. More on that later.

There are many designs for small FM transmitters on the Internet. Most of what you find look something like Figure 1. Q2 is a common-base oscillator with frequency set by L, C3, and the base-collector junction capacitance. RF on the base is grounded through C2. Feedback is via C4. Modulation is achieved by applying audio to the base of Q2 which varies its base-collector capacitance.



■ FIGURE 1

There are problems with such a design. First, you need an audio amplifier (Q1) to get enough modulation. Second, the antenna (the load) is attached directly to the collector (a high impedance source). Third, L usually must be wound by hand and adjusted by stretching. Fourth, C3 is often a "gimmick" capacitor: two pieces of insulated wire twisted together. It all adds up to a weak signal that tends to drift in frequency. And if things go really wrong, you get "motor-boating" (or squegging) as Q2 goes in and out of oscillation at an audio rate.

In contrast, the design in this article uses a common-collector oscillator which eliminates the possibility of motor-boating. It uses a varactor diode for tuning and modulation, giving great sensitivity without an audio amplifier. It uses an emitter-follower RF power amplifier to drive the antenna. It uses an inductor etched into the printed circut board (PCB). It puts out a strong signal with little drift.

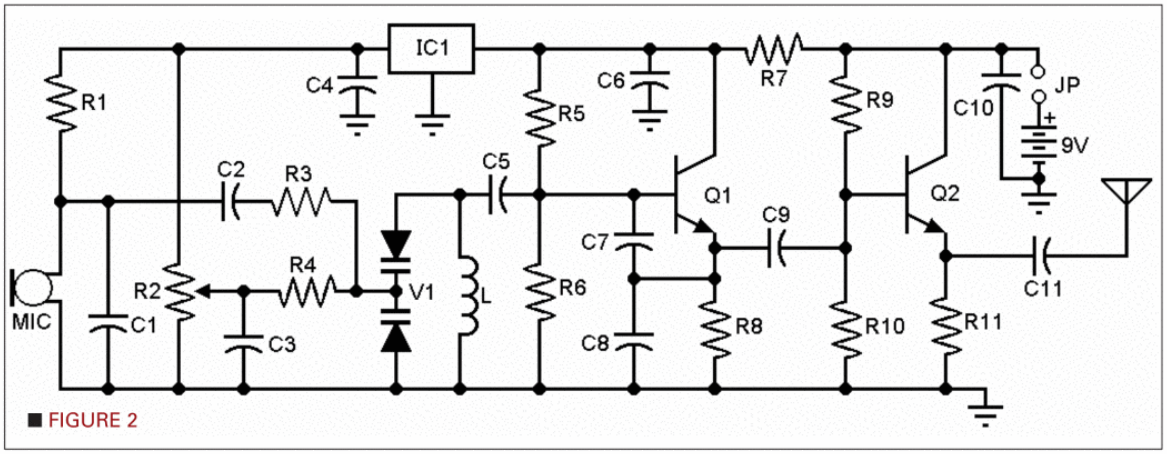
How It Works

The Circuit

Figure 2 shows the schematic of the transmitter. It consists of two stages: an oscillator and an output amplifier. Modulation is from an electret microphone.

Oscillator Stage

Transistor Q1 is configured as a Colpitts oscillator. The frequency of oscillation is determined by the parallel resonant circuit (tank circuit) formed by inductor L,



■ FIGURE 2

varactor V1, and capacitors C7 and C8 (C7 is big enough to swamp out stray capacitance from Q1). Note that Q1 is a common-collector amplifier (i.e., an emitter-follower) with the tank circuit from base to ground. That might seem surprising since an emitter-follower has a voltage gain of less than 1. But for an oscillator, it's power gain that counts. As long as the amplifier replaces the signal power lost in resistance, the oscillation keeps on going.

V1 is actually a dual varactor to eliminate the possibility of forward conduction at the sinewave peaks. The frequency of oscillation is set by adjusting the DC voltage on V1 with potentiometer R2 (see the sidebar on varactors). R4 and C3 form a low-pass filter to prevent RF from feeding back onto the DC. C5 couples the tank circuit to the base of Q1, but blocks the DC bias (of R5 and R6) from shorting to ground through L. Capacitors C7 and C8 form an AC voltage divider to provide feedback at the emitter of Q1 to sustain oscillation. A necessary condition for oscillation to start is for the ratio (C7 + C8)/C7 to be sufficiently bigger than 1.

Modulation

Modulation is done by superimposing an audio signal onto the DC bias applied to V1. The audio comes from an electret microphone (MIC). Since the electret mic has a built-in FET amplifier, it supplies a relatively large signal. The audio is applied to V1 via C2 to block DC. R3 serves two purposes. First, R3 and C1 form a low-pass filter to prevent RF from feeding back to the microphone. Second, R3, R4, and R2 form a voltage divider for the audio. Increasing R3 decreases the sensitivity of the microphone. DC to power the mic is fed through R1, which also sets the gain of the FET amplifier. IC1 provides a regulated five volts to power the microphone and its built-in amplifier.

For detailed information about Colpitts oscillators, see these websites: **www.ee.adfa.edu.au** or **www.rfic.eecs.berkeley.edu**

Output Stage

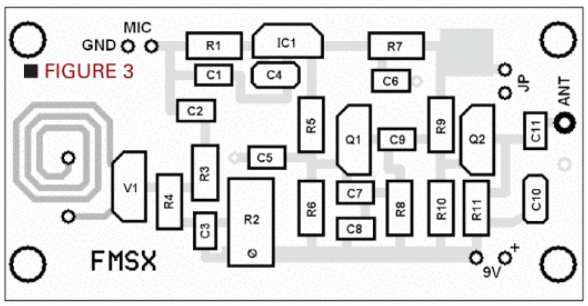
The output of the oscillator is fed through C9 to the Q2 emitter-follower. The output of Q2 drives the antenna through C11. The Q2 emitter-follower does two things for the circuit. First, it ensures that the oscillator is not loaded down by the impedance at the antenna. Second, it provides power gain to drive the antenna.

DC Power Decoupling

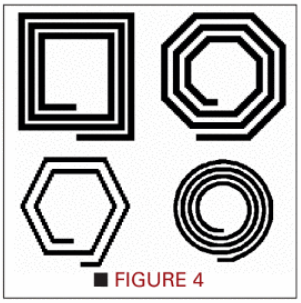
The transmitter is powered by a standard 9V battery. As the battery ages, its internal resistance increases and as current is drawn there is a voltage drop across that resistance. Since the current in Q2 varies with the 100 MHz signal, you get an RF ripple voltage across the battery. C10 is there to bypass that RF. Also, R7 and C6 form a low-pass filter to make sure that any ripple that C10 didn't remove is blocked from feeding back along the DC rail.

The Layout

Figure 3 shows the layout of the PCB. Since this was my first SMD project, I wanted to keep it simple, so the only surface-mount devices I used were resistors and capacitors (non-polar devices). To make it easy to tell the caps from the resistors, all the caps are size 0805 and all the resistors are size 1206. I used through-hole capacitors for C4 and C10 because I first built this circuit with all



■ FIGURE 3



■ FIGURE 4

standard components and just didn't change those two caps when I changed it to SMD. You can modify the design to use SMD components instead.

I used through-hole components for Q1, Q2, IC1, and V1. If you want, you can use an SOT-89 device for IC1 (Digi-Key NJM78L05UA) and an SOT-23 device for V1 (Digi-Key MMBV109LT1GOSCT). You'll have to find your own SMD transistor equivalent to the MPSH10 used here.

The Inductor

Since the circuit operates around 100 MHz, a relatively small value of inductance is required. A coil would consist of two or three turns of wire. It would be tricky to get the right value, and it would be sensitive to any stresses that might bend or stretch the coil. A coil would also be sensitive to vibration, causing "microphonics" as the vibrating coil varied the frequency of oscillation. All in all, it seemed better to form an inductor with loops of copper on the PCB. Such flat spiral inductors are common at these frequencies. (see Figure 4.)

You can find formulas on the Internet for designing PCB inductors. At best, they give you a ball-park estimate. Getting the right value requires some trial and error. One formula for flat spiral inductors is:

$$\frac{r^2 N^2}{8r + 11d}$$

where

L = Inductance (µH)

r = Mean radius of coil [outer radius plus inner radius divided by 2] (inches)

N = Number of turns

d = Depth of coil [outer radius minus inner radius] (inches)

In this design, the same spiral is etched on both sides of the board with the ends connected by pads. That was done to double the surface area since at 100 MHz, the skin effect is significant. It's the same reason why Litz wire is often used to wind RF inductors.

Tuning Range

While the commercial FM band goes from about 88 MHz to 108 MHz, the L and C values used in this design allow tuning up to about 100 MHz. In my part of the country, the clear spots on the FM band are at the low end, so it wasn't a problem. If you need to get to the high end of the band, use a varactor with less capacitance or remove one turn off the inductor.

VARACTORS

A varactor (or tuning diode) is a diode designed to be used as a voltage controlled capacitor. Its schematic symbol is shown in Figure SB1. A diode starts as a piece of intrinsic mono-crystalline material. Intrinsic means it contains no atoms of other material. Mono-crystalline means it's one single crystal with all the electrons trapped in covalent bonds between atoms. Basically, it's piece of rock; and it's an insulator.

FIGURE SB1

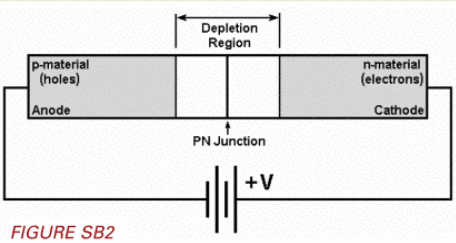


FIGURE SB2

To form the PN junction that makes a diode, half the piece is doped with a trace amount of "donor atoms" that have one more electron than the intrinsic stuff to make N-material. The other half is doped with a trace amount of "acceptor atoms" that have one less electron than the intrinsic stuff; they form "holes" in the crystal that can trap electrons. Those holes make P-material. Since the doped material contains charge carriers, it conducts a bit. It's a semiconductor.

To see how a varactor works, look at the reverse-biased PN junction in Figure SB2. You had "loose electrons" moving around the N side as far as the junction. Likewise, you had "loose holes" moving around the P side as far as the junction. But the battery pulls electrons out of the N side and pushes electrons into the P side (which fill holes) until the charge stored in the diode balances the battery voltage. That forms a region on both sides of the junction— the depletion region— that contains no loose charge carriers. The depletion region cannot conduct, so it's an insulator. On either side of that insulator you have conductive regions. Two conductors separated by an insulator form a capacitor, so a reverse-biased PN junction is a capacitor. The equation for capacitance is

$$C = (\varepsilon_r \varepsilon_0) \ A/d$$

where

***C** Is The Capacitance in Farads*

***A** Is The Area of each plate, measured in square meters*

ε_r Is The Relative Permittivity (dielectric constant) of the insulator

ε_0 Is The Permittivity of free space (8.854×10^{-12} F/m)

***d** Is The Separation between the plates in meters*

But d is the length of the depletion region which depends on V—the reverse-bias voltage. As V increases, d increases, and C decreases. There's your voltage controlled capacitor. Any diode can be used this way, but most diodes are designed to minimize junction capacitance. Varactors are specifically designed to be used as capacitors.

Building It

Soldering the SMD Chips

At first, I tinned all the circuit board pads for the SMD chips before trying to mount them. That was a mistake. With both pads for a chip tinned, heating up one end of the chip caused the situation shown in Figure 5. When heat was applied to the other end, the chip would not seat properly since the first end was frozen in place by the solder.

The trick was to tin only one circuit board pad of each SMD chip. Then, when heat was applied to the chip at the tinned pad, it seated nicely as shown in Figure 6A. Then solder was applied to the other end of the chip to get the result shown in Figure 6B.

To solder SMD chips to the board, you will need four things:

1) A good soldering iron. Initially, I used a 25W iron because I thought I had to. I found that it was much easier with my good old Weller model W60P temperature-controlled iron.

2) A suitable pair of tweezers is essential. I used a 4.5 inch curved pair (Electronix Express #06041043: **www.elexp.com**).

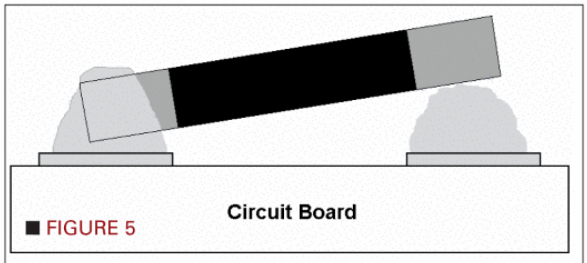


FIGURE 5

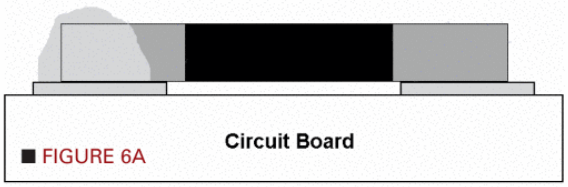


FIGURE 6A

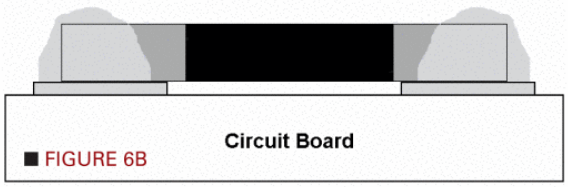


FIGURE 6B

C versus V

Figure SB3 shows the graph of C versus V for the MV104 varactor used in this project. The MV104 is a dual-diode; SB3 is for one diode.

An important specification for a varactor is CR, the ratio of its capacitance at two specified voltages. For the MV104, the capacitance ratio is specified at 3 volts and 30 volts.

$$C_R = C_3 / C_{30} = 2.5$$

The two types of varactors commonly used are called abrupt and hyper-abrupt. The terms refer to the doping profiles used in the semiconductor. Hyper-abrupt varactors exhibit a larger change in capacitance per volt, so their CR is greater; but their Q is usually lower. Some hyper-abrupt varactors are designed to linearize the frequency versus voltage characteristic when used in a tuned circuit with f = 1/[2 sqrt(LC)].

The relationship between C and V is not linear, so the graph in figure SB3 is logarithmic on both axes. The equation for C as a function of V is

$$C = C_0 / [1 + (V_R/V_P)]^g$$

where

C *= Capacitance of varactor*

C_0 *= Capacitance of varactor when* V_R *is zero*

V_R*= Reverse Voltage applied to varactor*

V_P*= The diode contact potential (≈ 0.6V for silicon 1.2V for gallium arsenide)*

g *= Tuning slope of C-V curve (≈ 0.5 for abrupt varactor; 0.75→1.5 for hyper-abrupt)*

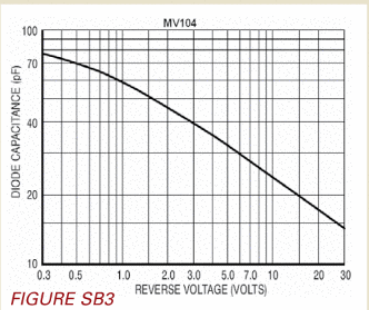


FIGURE SB3

Q versus V

Another important property of varactors is how their figure-of-merit (i.e., quality-factor Q) changes with voltage. The effectiveness of the transmitter's LC tank circuit depends on its Q. Figure SB4 is the Q vs. V graph for the MV104. Note that Q increases with voltage, while C decreases with voltage.

Applications

Because of their relatively low capacitance values, varactors are used mainly at VHF frequencies and above. Varactors are used to make voltage—controlled oscillators (VCOs) like the one in this project. They are used in TV tuners and some radios, as well as in tunable filters. They are also used in frequency multiplier circuits.

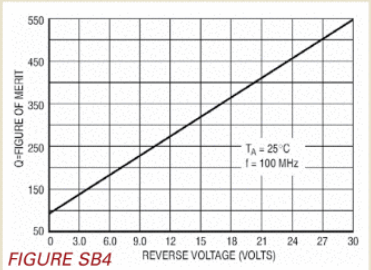


FIGURE SB4

3) A head-mounted binocular magnifier (the kind you can flip up and down as needed). You can get an inexpensive one from several vendors. All Electronics has one for $4.95 (#HD-MAG); **www.allelectronics.com**.

4) A board vise (or something similar) to hold the PCB securely while you work on it.

Before you start soldering the SMD chips, make sure you've separated them into groups and tagged each group with its value. You can use something like a hinged plastic box that is divided into compartments, but make sure the compartments can't leak into each other. Note: The resistor chips are printed with numbers that show the value (e.g., 103 = 10K), but the capacitor chips are not marked. So be careful.

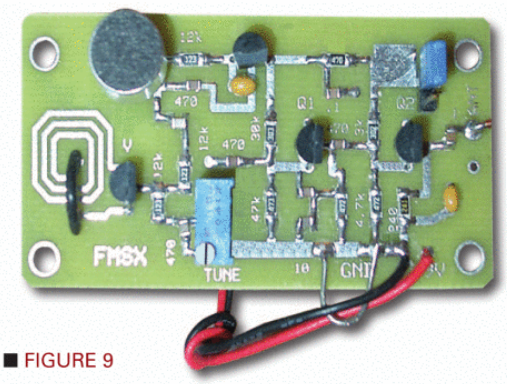
Once you've tinned the pads (remember: only one pad per chip), you pick up a chip with the tweezers and position it onto its set of pads. While holding it in place with the tweezers, you heat the tinned end until the solder melts and adheres to the chip. Let this cool. Remove the tweezers and solder the other end. The chips are small, so don't use too much solder. Don't hold the iron on the chip too long. With a good iron, it should take just seconds.

It helps to use an iron with a steel-clad tip instead of a solid copper tip. Be sure to keep the tip clean. The traditional damp-sponge cools off the tip and can foul the tip if the sponge burns. I much prefer a brass-wool pad. A company called XYTRONIC makes them, and you can get them from several vendors (Electronix Express #0603460).

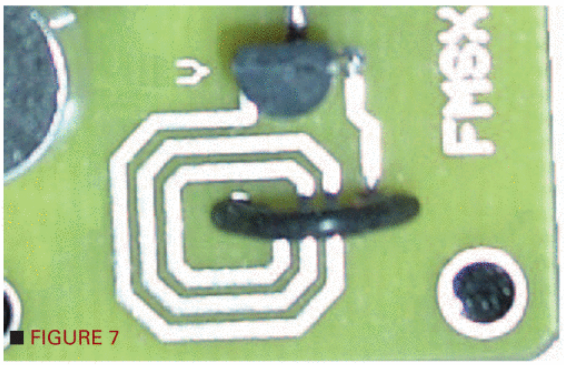
I'm sure there is an officially correct way to solder SMD chips that differs from my procedure. I'm just telling you what worked for me.

First Inspection

After you've soldered all the SMD chips to the board, clean off any flux residue with some rubbing alcohol and an old tooth brush. Then give it a close visual inspection with your binocular magnifier and look for bad solder joints and solder bridges. Touch up any problems with your iron.



■ FIGURE 9



■ FIGURE 7

The Rest of the Parts

Mount the two-pin male header to the board and solder it in place. Then mount the potentiometer, the through-hole caps, the 78L05, the transistors, and the varactor. Solder them in place. The electret mic is polarized; its metal case is ground. Be careful to insert it with the positive end near R1. Don't push it flush; leave about 1/4 inch between the mic and the board. Solder it in place.

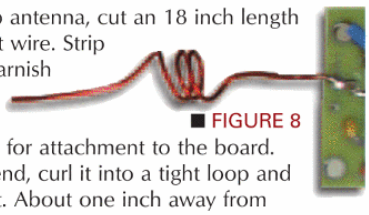
You need to solder a jumper to connect to the pad in the center of the inductor (see Figure 7). Use a short piece of insulated, solid hook-up wire — as short as is practical. The length of the jumper adds to the inductance.

Second Inspection

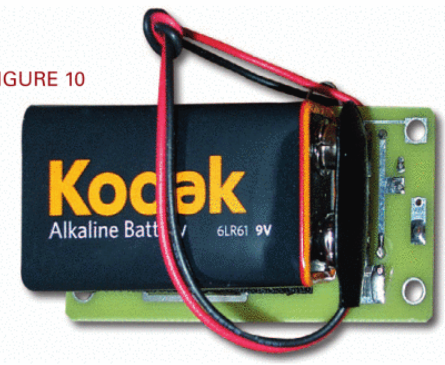
Again, clean off any residue and give the board a good visual inspection. Make sure that the leads of the through-hole parts are trimmed close to the board.

Mount the Antenna

To make a whip antenna, cut an 18 inch length of 18 gauge magnet wire. Strip about 1/2 inch of varnish off both ends and tin them. Bend one end into an L shape for attachment to the board. To blunt the other end, curl it into a tight loop and solder the loop shut. About one inch away from the L shaped end, make a three-turn coil by wrapping a portion of the wire around a wood pencil (see Figure 8).



■ FIGURE 8



■ FIGURE 10

The coil in the antenna does three things:

1) It gives the antenna a little springiness so it snaps back if bent slightly.

2) Series inductance makes the electrical length of the antenna longer than its physical length. The wavelength (λ) at 100 MHz is three meters, or about118 inches. Power radiated would be higher if the electrical length was equal to λ. To make that happen you would need to calculate the required inductance and the inductance of the coil.

3) It looks cool.

If you don't want a whip antenna, then a length of stranded insulated hook-up wire will work. Use a length that gives you the best range; maybe 20 to 30 inches or so.

PARTS LIST

RESISTORS

❑ R1	12K
❑ R2	100K Pot (*)
❑ R3	12K
❑ R4	470Ω
❑ R5	30K
❑ R6	47K
❑ R7	47Ω
❑ R8	4.7K
❑ R9	3K
❑ R10	4.7K
❑ R11	240Ω

CAPACITORS

❑ C1	470 pF
❑ C2	0.1 µF
❑ C3	470 pF
❑ C4	0.1 µF
❑ C5	470 pF
❑ C6	0.1 µF (*)
❑ C7	27 pH
❑ C8	10 pH
❑ C9	470 pF
❑ C10	0.1 µF
❑ C11	0.1 µF (*)

SEMICONDUCTORS

❑ Q1	MPSH 10 (*)
❑ Q2	MPSH 10 (*)
❑ V1	MV104
❑ IC1	78L05 (*)

HARDWARE

- ❑ Printed Circuit Board FMSX
- ❑ Electret Microphone
- ❑ Battery 9V
- ❑ Battery Clip
- ❑ Two-Pin Male Header
  0.1 inch centers
- ❑ Header Jumper
- ❑ Hook-and-loop Strip

(*) Non-SMD

Mount the Battery

First, solder the battery snap-connector to the PCB near the antenna end as shown in Figures 9 and 10.

Next, get a length of hook-and-loop strip (RadioShack #64-2345 or equivalent) and cut off a one inch piece. Separate the two halves. Peel the backing off one half and attach it to a 9V battery. Peel the backing off the other half and attach it to the back of the PCB. The half on the PCB should be positioned so that when the battery is attached to the board, the assembly will stand up on a flat surface (see Figure 10).

The on-off switch is a shorting jumper seen in the upper left corner of Figure 9. When placed across the two-pin header strip, it connects power to the circuit. When the jumper is removed, power is disconnected. (Note: The small loop of bare wire soldered to the board in Figure 10 is a place to clip the ground lead of a scope or meter.)

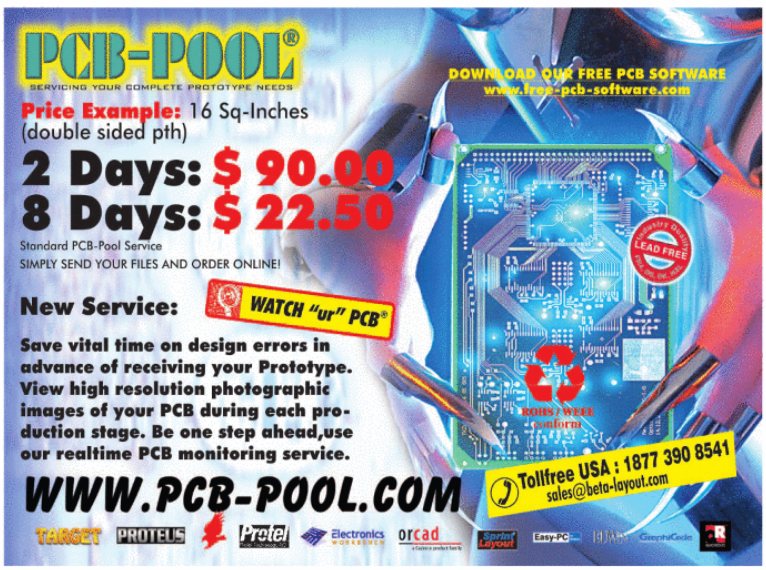
Testing

You will need a portable FM radio. Also, it helps to have an assistant. First, find an empty spot on the FM dial and set your radio to that frequency. Have your assistant take the radio about 30 feet away. The radio's volume control should not be set too high to prevent feedback; if the radio has an ear-piece, use it. Next, power up the transmitter. Talk to yourself as you adjust the frequency with the trim-pot (talk softly, the mic is very sensitive). When your assistant hears you, your transmitter is tuned. You might have to adjust the radio's tuner slightly for best reception. When done, remove the jumper to conserve the battery.

Conclusion

Have fun with it! But remember that using the transmitter as a bugging device may not be legal. To use the transmitter as a wireless microphone, increase the value of R3 to reduce the sensitivity of the electret mic. I've used it over a distance of 100 feet inside a building, and it worked fine. **NV**

The PCBs and/or a complete kit with SMT or TH components for this project can be purchased through the *Nuts & Volts* Webstore. See ad on page 90.



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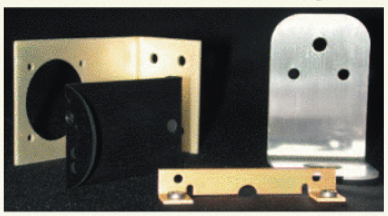

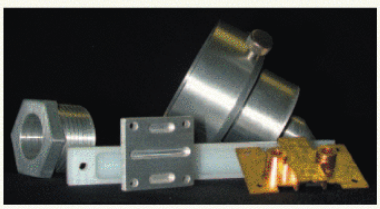

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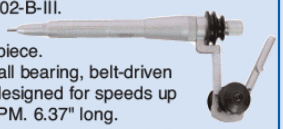

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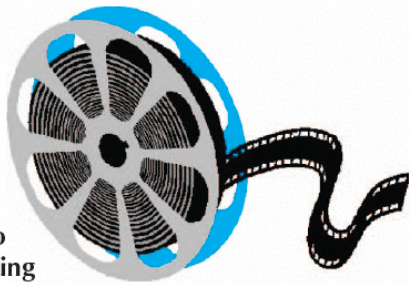
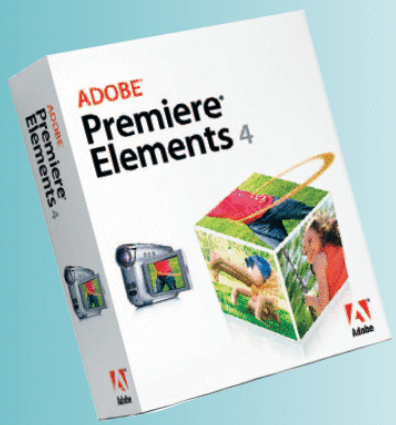


Ever completed a killer electronics project and wanted to share your results with the world? We discussed text-oriented blogging in the August '05 issue of *Nuts & Volts*, and audio podcasting in the March '07 issue, but why not add moving pictures into the mix, and launch your own video blog?

by Edward B. Driscoll, Jr.



While Adobe's Premiere Elements program lacks all of the features of its big brother, Adobe Professional, it's surprisingly powerful for a program aimed towards video beginners.

It's hard to beat the immediate, visceral impact of moving images, and 80 million or so people a month tune into YouTube (**www.youtube.com**), making it the equivalent of a hugely popular TV channel — with no painful audition process in order to be on it. And once your video is on YouTube, it's a snap to embed it into an-otherwise text-based Weblog, including our own *Nuts & Volts* blog at **www.nutsvolts.com**.

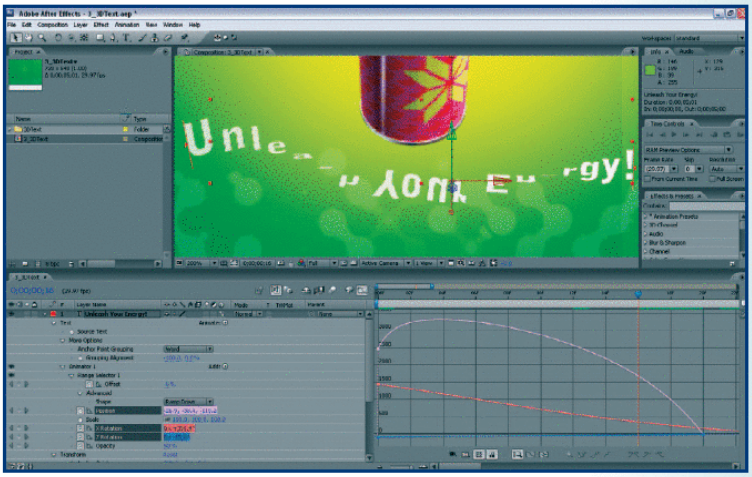
The Great Equalizer

For those who've never shot video before, the prospect of learning the mechanics of online video can be an intimidating prospect. But fortunately, YouTube is a great equalizer. Its tiny video screen, displaying videos with a resolution of 320 by 240 pixels, looks dwarfed on the typical PC's LCD monitor screen. And already, its video quality has been superseded by the quality of several other, sharper, newer video aggregation sites.

But as a result, YouTube is awfully forgiving, particularly as a training ground. It's free to use and has the potential to allow thousands — or even more — to see your video.

On YouTube, it's the concept that counts as much as the finished product. Since the maximum length that YouTube normally allows is 10 minutes — and most videos on the site are half that length or less — you can't get *too* self-indulgent and meandering (two sins that bedevil new videomakers both young and old with visions of Spielberg and Lucas dancing in their heads).

Not surprisingly, a relatively up-to-date computer — ideally with aftermarket video and sound cards — is necessary for video. And you'll need an editing program, of course, to assemble the myriad of shots that go into your video



In addition to sophisticated video processing, Adobe's After Effects CS3 allows for complex text animation, ideal for slick, professional titles.

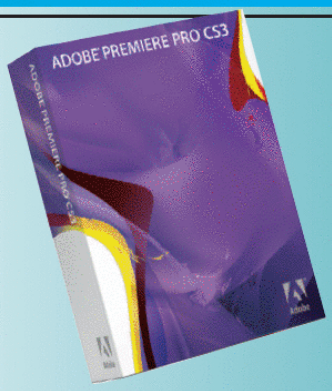
into a timeline from beginning to end. These programs include Sony Vegas, Adobe Premiere Pro, and its junior brother, Premiere Elements. However, this article is primarily concerned with getting the best possible picture and sound into those programs.

Building a Virtual World Inside Your Garage

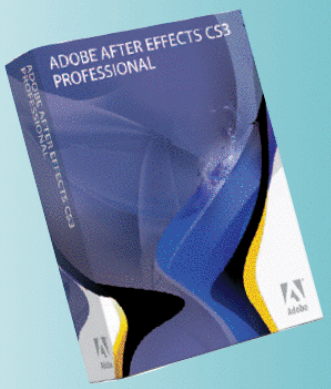
There are plenty of one-man, one-camera, one-take, unedited videoblogs on YouTube with substantial audiences, and that's certainly a good way to start. But why not try to go beyond that? After all, PBS's *This Old House* makes watching homebuilding much more interesting than raw video of your local contractor at work. On video, a smooth, tightly-edited presentation can make even the most esoteric subject that much more approachable, particularly to the layman. As a way to easily spruce up a one-man video production, consider recording yourself talking about your project while standing on a virtual set.

Virtual sets take advantage of a once-reviled technology: chromakey. When chromakey first debuted on the local television level in the mid-1970s, it was mostly associated with weathermen clad in garish plaid polyester jackets standing in front of cheesy maps of Poughkeepsie or Sheboygan. Of course, the goal was to shoot the weatherman in the studio against a solid-colored background, then electronically delete the background and insert various images, from maps to on-location video. But very often, the key would be imprecise, causing said

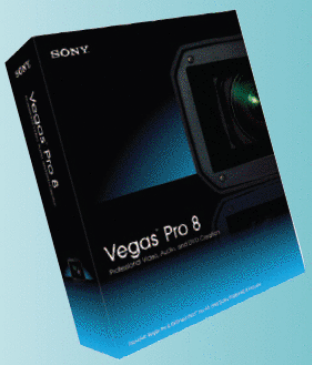
A combination of a green screen backdrop and a chromakey program allows for any number of simulated video backdrops, including this virtual museum from Adobe's Ultra2 program for Windows.



The latest iteration of Adobe's 17-year old Premiere platform, Premiere Pro CS3 is an industry-standard video timeline editing program.



Adobe's After Effects CS3 applies Photoshop-style photo manipulation techniques to moving video.



Sony's Vegas Pro 8 has recently emerged as an increasingly popular video editing program.

Well-lit video is the essential building block for a video production, and with both traditional hard lighting sources and a softbox for more diffused looks, Lowel Light Manufacturing Inc.'s DV Creator 44 kit is an excellent starter set.

weatherman to appear to be dematerializing into his map.

But that was long ago. These days, chromakey and related technologies such as blue and green screen effects have gotten so exact, they're the key to Hollywood blockbusters ranging from the recent batch of *Star Wars* prequels to such quasi-comic book films as *Sky Captain*, *Sin City*, and *300*.

One reason why these effects have taken off in the past few years is that compositing via PC has become incredibly sophisticated. And that technology has rapidly trickled down to the consumer level.

Once this model standing in front of ImageWest's 10X15-foot green screen is videotaped, the chromakey applet built into many video editing programs can quickly and easily replace the green backdrop with a photograph or a virtual set.

While Hollywood films still have multi-multi-million dollar budgets, green screen effects have actually saved them considerable sums by allowing sets to be built in a computer, not by draftsmen and riggers. Similarly, because compositing via PC is now inexpensive enough that the average serious hobbyist can afford it, green screen effects allow one-man video podcasts to have an extremely slick look, even if they're shot in a garage or a basement. They also simplify lighting. Rather than having to carefully light a whole room, small, affordable lighting kits, such as those manufactured by Lowel (**www.lowel.com**) – can be used to aim two or three lights at the talent (the key, fill, and hair light), and another pair of lights at the green screen behind said talent.

So, let's look at some of the elements involved in producing a successful key.

While there are plenty of keying programs for both Mac and Windows (and many video editing programs come with a keying applet built in), Adobe's Ultra 2 (only for Windows, unfortunately) is significant for three reasons. The first is that unlike some of the more primitive keying programs, its software builds a virtual map of the green screen behind the actor, which means that if the green screen and actor are properly lit (more on this in a moment), it can generate an extremely tight key. The second is that it's extremely easy to use, particularly if you have a shot of the green screen without the actor for the program's software to do its thing.

The third is that a whole host of virtual sets can be purchased to place a variety of extremely slick digital backdrops behind an actor.

What does this mean? It means that a green screen can be hung in a garage or basement, a handful of lights placed in front of it, and via a standard DV handycam, your garage can be transformed into a television newsroom, a talk show, a corporate boardroom, a classroom, and on and on. You can even have helicopter shots zooming into science fiction backgrounds that Gene Roddenberry would have given his eye teeth for during the heyday of *Star Trek*. Additionally, photographs of anything from the exterior of your local Best Buy, to the interior of the Starship Enterprise can be used as a backdrop. And none of these backdrops have to be lit. So, all of a sudden, a one-man video podcast starts to look increasingly slick and inviting.

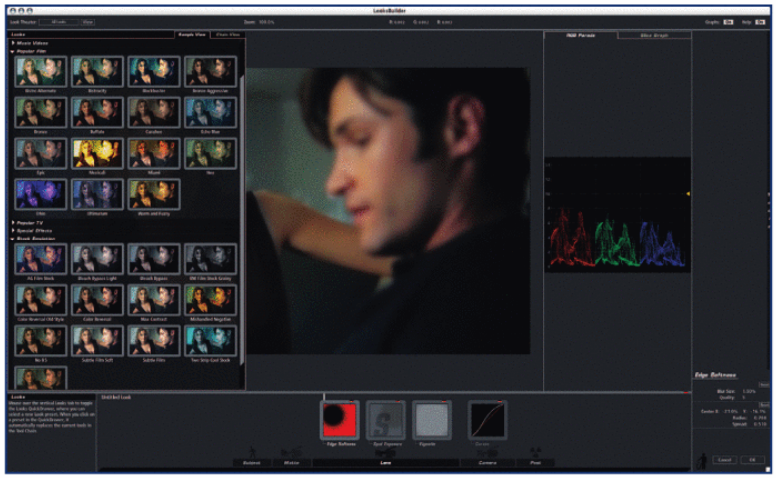
A portable green screen is fine for temporary set-ups, but if you have the space, aim for a green screen wide enough to go to floor to ceiling to take advantage of these virtual sets. Also, you may want a separate tabletop lighting system for close-up shots of your project.

Many of the virtual sets that Adobe sells for Ultra 2 have virtual computer monitors and television screens positioned within them, which allows for additional video clips to be composited into them. These are great for having your project on display in the background as you

talk. If you also want to comment on the news of the day, Mozilla's popular Firefox browser has a third-party applet available at **www.downloadhelper.net** that will pull any video off YouTube and some other video hosting sites, as well, that also use Flash video. Applian Technologies' Replay Converter (**www.applian.com**) will convert these Flash clips to a Windows .AVI file that's compatible with Ultra. Drop a news clip into one of the virtual monitors built into Ultra's myriad of virtual sets, and presto! Instant anchorman! (Preferably with more brains than Ron Burgundy.)

Another advantage of Ultra is that it makes shooting relatively simple. It relies on three basic angles: long shot, medium shot, and close-up. These are generated by a camera locked down on a tripod. Camera movements are handled within the Ultra program.

Which brings up a good point: When preparing any video for YouTube, videos shot with a tripod will render more crisply than an endless handheld shot. In other words, *The Blair Witch Project* should not be your normal visual reference.



Magic Bullet Looks provides a variety of default color schemes, many of which are based on the looks of popular TV series.

The Magic Bullet Theory

As Stanley Kubrick once said, "If I wanted to be frivolous, I might say that everything that precedes editing is merely a way of producing film to edit." After your basic footage has been videotaped and/or chromakeyed, assembling and editing within a timeline program such as Adobe's Premiere Pro or Sony's Vegas is the next stage.

Numerous books have been written on the art and theory of editing, but for your first clip as you assemble the various shots within your editing program, concentrate on basic narrative flow. Try to look at the material with fresh eyes, and ask yourself how this will be received "cold" by whoever you imagine your typical viewer will be.

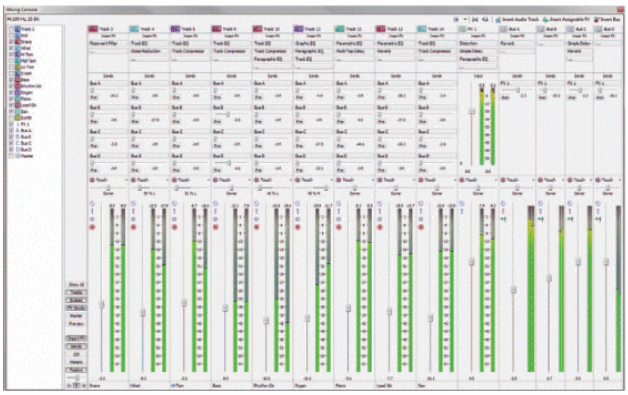
As your video skills increase, you may want to begin to stylize some or all of your edited footage for a unique atmosphere or look, and a program such as Red Giant Software's Magic Bullet program (**www.redgiantsoftware.com**) can create some powerful atmospherics. It can generate a *Matrix*-like green tint, or those *CSI: Miami* orange sherbet skies, or a soft film-like sheen with plenty of diffusion, or anyplace in between. Magic Bullet also comes with a separate plug-in called Misfire, which can add scratches, grain, blotches, and other film-like effects, if you'd like to beam a few shots back from the 1950s.

Magic Bullet will probably require an aftermarket videocard to do its stuff; it coughs and sputters when it sees the typical built-in video adapter on a stock PC's motherboard. You'll likely want to get a more powerful videocard anyway, for both faster rendering of videos, and for dual monitor support. You'll find your videos are much easier to edit and assemble with the video tracks on one monitor, and the editing program's preview screen on another.

Sound is 50 Percent of the YouTube Experience

Shure's SM93 microphone, designed for use with video cameras equipped with professional-style XLR jacks, is smaller than a paperclip, and can be clipped to a tie or lapel, allowing for finely detailed recordings via a remarkably unobtrusive microphone.

George Lucas is fond of saying that "Sound is 50 percent of the moviegoing experience" — and not just because it helps sell home theater components branded with his proprietary THX Sound logo. Sound is also a surprisingly crucial part of the Internet video experience, as well. The consumer-grade digital video camcorders sold at Best Buy and the like can generate decent-enough video for YouTube, but their onboard mics often leave something to be desired. Fortunately, there are several ways that their cheap mics can be overcome. First, if the camcorder has a built-in mic jack, by all means plug a separate mic into it. Alternatively, some firms, such as BeachTek (**www.beachtek.com**), make adapters that serve as a base for the camcorder, and allow microphones equipped with professional XLR jacks to plug into select consumer-grade camcorders.



With controls resembling those on an actual mixing desk found in a video editing suite, the Vegas Pro 8 mixing console GUI allows for carefully detailed audio tracks.

There are numerous consumer-grade camcorders that don't even have a 1/8-inch miniplug for a mic built into them. If that describes your current DV camera or you don't want to buy the adapter base, consider recording narration after editing your video, or use a portable digital recorder to record your voice. Prior to owning a "pro-sumer" quality Sony HVRA1U HD camcorder, I used a Zoom H4 (**www.samsontech.com**) digital Handy Recorder to record my voice while recording video with a consumer-grade DV cam. I could plug a professional Shure SM-58 handheld mic (**www.shure.com**) into one of its two XLR inputs, or simply hold the recorder in my hand and talk into it, since it wasn't much larger than a microphone itself.

If your audio is recorded separately, how do you easily sync up the sound? For decades in Hollywood, audio was recorded with a tape recorder, and then synced to the picture in the editing room. To simplify the mating of sound and picture, Hollywood relies on clapperboards to simultaneously generate a loud audio *CLACK!* and then the filmed image of its two boards come together as a visual cue to sync up the sound and picture.

Sony's Vegas Pro 8 Multicam interface allows for editing of scenes originally shot with multiple video cameras running simultaneously.

That basic method (or a more primitive version such as a handclap on camera) has worked since the earliest days of the first talkies in the late 1920s, and is one option to consider if you're recording audio into a digital recorder. Another is to use the audio from the camcorder's built-in low-res mic itself as a guide. Most editing programs generate a visual image of the waveforms of the audio. By sliding the waveform image of the separately recorded audio track until it's aligned with the waveform image recorded by the camera's mic, it's possible to sync the two remarkably tightly, particularly if your editing program can be switched into audio time units, which are much, much finer a resolution than the 30 frames a second of video.

There are several options open to successfully mic'ing on-air talent, including shotgun mics, handheld mics, and clip-on lavaliere mics, so some experimentation may be necessary to find the approach that works best in your situation. And again, the YouTube environment is somewhat forgiving, but in general, the closer to the talent's mouth, the better. Shure's SM93 lavaliere, for example, is smaller than the size of a paperclip, and can easily be clipped to a lapel or necktie. A handheld mic such as Shure's SM58 can do double-duty as both an in-the-field mic, and a tabletop mic for voice-overs.

For editing audio, owning a separate digital audio workstation (DAW) program such as Cakewalk's Sonar XL (**www.cakewalk.com**) is a huge benefit to a video producer. Multiple narration tracks can be easily recorded and edited together, audio compressed and normalized so that both the main and B-Roll elements play at the same apparent volume, and background noise from a remote shoot can easily be edited out by importing audio from the video editing program into the DAW. For extreme situations, an applet such as Bias, Inc.'s, SoundSoap Pro (**www.bias-inc.com**) or Izotope's RX (**www.izotope.com**) can do wonders to salvage an audio track otherwise ruined by hum or wind. A DAW also facilitates audio-only podcasts, as well. For much more on recording podcasts with a digital audio workstation, see the article on the topic in the March '07 issue of *Nuts & Volts*.

Rendering Unto YouTube

Assuming you're happy with how the video looks, sounds, and flows, it's time to render it into a format that's acceptable to YouTube, or whichever site you're uploading to.

You may have compiled tens of gigabytes of material, including multiple takes of your on-camera lines, narration tracks, and separate B-Roll footage of the electronics project that's the subject of your video, but it all needs to be boiled down to a clip that's under 100 megabytes in

file size, and under 10 minutes in length.

YouTube ultimately converts video to the Flash video format for streaming via an Internet browser and typical broadband speeds. So, if your editing program allows for final rendering in that format, you should be good to go — but even then, you'll probably need to tweak the settings to find the best mix between quality and file size. Otherwise, YouTube will convert .MPG, .AVI, .MOV, and .WMV formats, but you may not like the distortions imposed during the conversion process.

Is There a TV Show in Your Future?

Once your video has been rendered, you're ready to upload it to YouTube, via their extremely easy-to-use interface. Be patient, though. It could be 15 to 20 minutes — or more — before your video completes the uploading procedure. And then another 15 minutes up to an hour or two before the video is online, after it's been processed and cataloged by YouTube itself.

Will you be happy with your first effort? No doubt, you'll see lots of errors you wish you could improve — but that's as good an excuse as any to do your second video.

Is there an online TV series on electronics in your future? There is if you want it to be! **NV**

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You may just see it posted on the NV video blog!!

Further Reading

Needless to say, one article can only scratch the surface of videomaking, even for YouTube. Whole books could be written on the topic of video making — and fortunately, several have. *Here are a few that I've found helpful:*

✦ *Producing Videocasts* by Richard Harrington and Mark Weisler (Focal Press, 2008). Most books on video are written for those who wish to produce corporate videos or are independent filmmakers. As its title implies, *Producing Videocasts* is written specifically for those who wish to enter the world of online video.

✦ *Setting Up Your Shots, Revised Second Edition* by Jeremy Vinyard, Illustrated by Jose Cruz (Weise, 2008). An illustrated guide to the grammar of Hollywood, with specific examples of Hollywood films for each composition and camera trick described herein. In addition to providing visual inspiration galore, we've been conditioned by a century of Hollywood filmmaking to understand certain shots and angles mean specific things. DIY video making is often about breaking the rules — but it helps to know what they are beforehand.

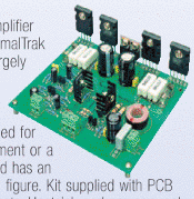
✦ *Bluescreen Compositing* by John Jackman (Elsevier, 2007). From Adobe's Ultra 2 to zillion dollar Hollywood shoots, this is an excellent primer to get up to speed fast on all facets of chromakey.

✦ *Producing Great Sound For Film & Video* by Jay Rose (Focal Press, 2008). There are a great many books on sound, but most of these are geared towards musicians. Many DIY videos have surprisingly mediocre sound; here's a thorough introduction to sonically set yours apart from the pack.

IDEAL KITS FOR ELECTRONIC ENTHUSIASTS

ULTRA LOW DISTORTION AMPLIFIER MODULE

KC-5470 $52.25 plus postage & packing



This ultra low distortion amplifier module uses the new ThermalTrak power transistors and is largely based on the high-performance Class-A amplifier. This improved circuit has no need for a quiescent current adjustment or a Vbe multiplier transistor and has an exceptionally low distortion figure. Kit supplied with PCB and all electronic components. Heatsink and power supply not included.

- Output Power: 135WRMS into 8 ohms and 200WRMS into 4 ohms
- Freq Resp. at 1W: 4Hz to 50kHz
- Harmonic Distortion: <.008% from 20Hz to 20kHz

NEW FOR 08

BRIDGE MODE ADAPTOR

KC-5469 $14.50 plus postage & packing

IDEAL FOR STEREO AMPLIFIERS. Lets you run a stereo amplifier in 'Bridged Mode' to effectively double the power available to drive a single speaker. There are no mods required on the amplifier and the signal processing is done by the kit before the signals are fed to the stereo amp. Ideal for say, using a stereo amp as an occasional PA amp for social functions or using an old amplifier to drive a sub-woofer in a home theatre.

- Kit supplied with silk screened PCB and all specified components.
- Requires balanced (+/-) power supply.

LOW COST DIGITAL MULTIMETER

QM-1500 $4.00 plus postage & packing

This full featured Digital Multimeter is perfect for the home handyman or young experimenter and will give years of reliable service. It features a huge 10A DC current range as well as diode and transistor testing functions. Also measures AC & DC volts and resistance. At this price you should buy two!

LED WATER LEVEL INDICATOR MKII KIT

KC-5449 $20.50 plus postage & packing

This simple circuit illuminates a string of LEDs to quickly indicate the water level in a rainwater tank. The more LEDs that illuminate, the higher the water level is inside the tank. The input signal is provided by ten sensors located in the water tank and connected to the indicator unit via-light duty figure-8 cable. Kit supplied with PCB with overlay, machined case with screen printed lid and all electronic components.

- Requires 12-18V AC or DC 500mA plugpack.

PIC LOGIC PROBE KIT

KC-5457 $8.75 plus postage & packing

Most logic probes are designed to operate on 5V rails. This design operates on a wide voltage range down to 2.8V so it's suitable for use on the most modern circuits. It's also extremely compact with SMT devices on a PCB only 5mm wide, so it will fit inside a very slim case. It's capable of picking up a pulse only 50mS long and will also detect and hold infrequent pulses when in latch mode. Kit includes PCB and all specified electronic components including pre-programmed PIC. You'll need to add your own case and probe - a clear ballpoint pen case and needle, works well.

STAINLESS STEEL TOOLS

5" Stainless Steel Long Nose Pliers TH-1888 $8.75 plus postage & pkg

Made from polished stainless steel, have a leaf spring and have serrated jaws..

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High quality small side cutters that have thick (2mm) blades and soft comfort plastic spring loaded handles.

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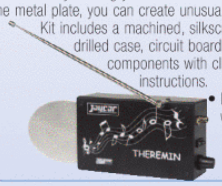
RR-0700 $10.00 plus postage & packing

Great for experiments or selecting the best resistance for a circuit. Choose from 36 x 0.25W 5% resistors ranging from 5 ohms to 1M ohms. Comes complete with leads and insulated crocodile clips.

THEREMIN SYNTHESISER KIT

KC-5295 $34.95 plus postage & packing

The Theremin is a strange musical instrument that was invented early last century but is still used today. The Beach Boys' classic hit "Good Vibrations" featured a Theremin. By moving your hand between the antenna and the metal plate, you can create unusual sound effects. Kit includes a machined, silkscreened, and pre drilled case, circuit board, all electronic components with clear English instructions.



- Required 9VDC wall adaptor

IR REMOTE EXTENDER MKII KIT

KC-5432 $14.50 plus postage & packing

Operate your DVD player or digital decoder using its remote control from another room. It picks up the signal from the remote control and sends it via a 2-wire cable to an infrared LED located close to the device. This improved model features fast data transfer, capable of transmitting pay TV digital remote control signals using the Pace 400 series decoder. Kit supplied with case, screen printed front panel, PCB with overlay and all electronic components.

- Requires 9 VDC power and 2-wire cable

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SMILEY'S WORKSHOP

AVR MICROCONTROLLER: C PROGRAMMING - HARDWARE - PROJECTS

by Joe Pardue

PART 2: Your First AVR Program
C'ing With Cylon Eyes

Get started now with this series! Joe's book & kit are available in our webstore at **www.nutsvolts.com**

This workshop is the second of a series that will introduce C programming for the AVR microcontroller based on the book *C Programming for Microcontrollers* by Joe Pardue available from **www.smileymicros.com** or *Nuts & Volts* (***www.nutsvolts.com***).

Last month, we learned where to get the software and hardware we'll need, built the AVR Butterfly-based AVR Learning Platform, and tested it with Developer Terminal. This month, we will write and compile our first C program using our AVR Learning Platform. This is not going to be the standard wimpy 'Hello World!" of yore, but a zippy software/hardware combination where we create some Cylon eyes. These aren't eyes of the cute, sexy Cylons of the recent Battlestar Galactica, but the old fashioned '70s walking chrome toaster Cylons of the original series.

■ FIGURE 1. Cylon.

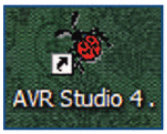
Getting Started With Free Stuff: AVR Studio and WinAVR

AVR Studio provides an IDE for writing, debugging, and simulating programs. We will use the WinAVR GCC C compiler toolset with AVR Studio via a plug-in module.

You can find these at AVRStudio (**http://atmel.com/dyn/products/tools_card.asp?tool_id=2725**) or WinAVR (**http://sourceforge.net/projects/winavr/**).

Install WinAVR first and AVR Studio second (use the default locations so AVRStudio can find WinAVR).

Click on the AVR Studio desktop icon (Figure 2). It opens with 'Welcome to AVR Studio 4' (Figure 3). Click on the 'New Project' button.



■ FIGURE 2.

In the 'Create new project' window (Figure 4), click on AVR GCC, add the 'Project name': 'CylonEyes,' and set the 'Location' to a convenient spot. Then click finish.

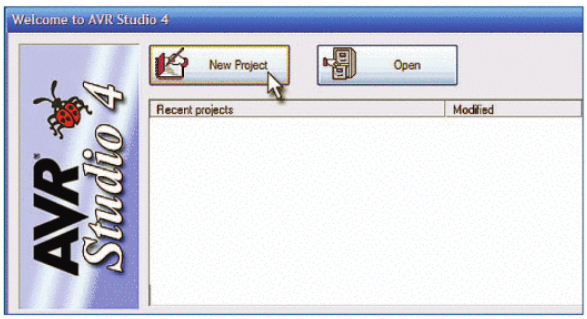
The IDE is somewhat complex, with lots of tools that we won't be using just yet, so try not to have heart palpitations. It will mostly make sense eventually.

Setting Up the Project Configuration Options

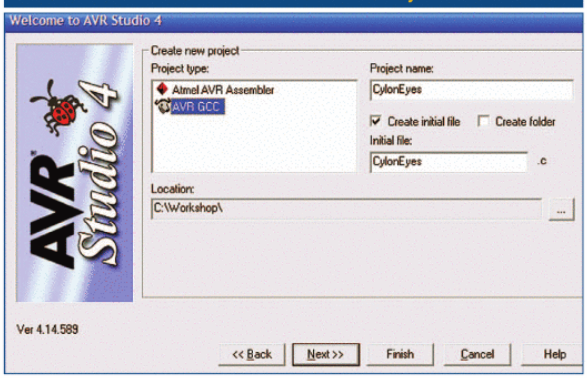
From the 'Project' menu item, select 'Configuration Options' (Figure 5).

In the 'Project Options' window, select the ATmega169 from the 'Device:' dropdown box (Figure 6).

■ FIGURE 3. Welcome to AVR Studio 4.

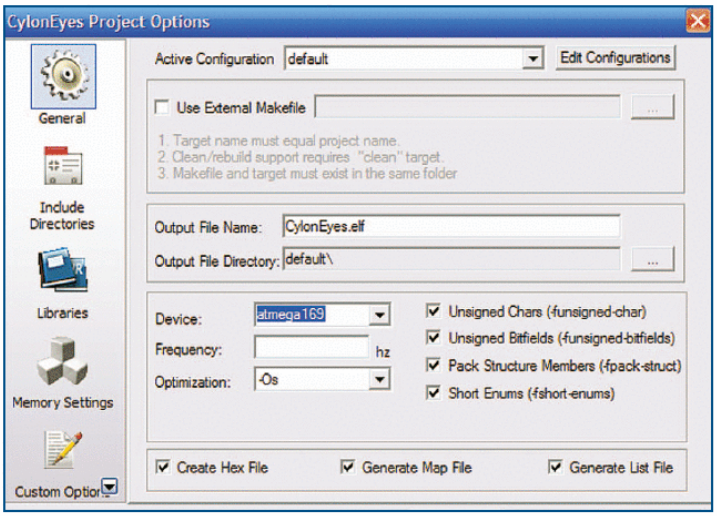


■ FIGURE 4. Create New Project.



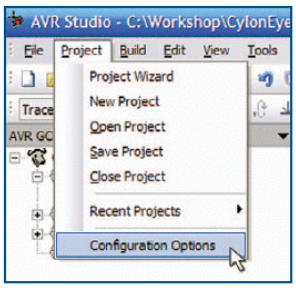
CylonEyes.c

You might wonder why blinking an LED is the first project, when traditional C programming texts start with a "Hello World!" program. The Butterfly has an LCD that can show the words so it should be easy, but controlling the LCD is much more complex than blinking an LED, so we'll save the LCD for later when we've gotten a better handle on things. Actually, the main reason is that I'm partial to LEDs so you are going to see a lot of flashing lights before we are through, and hopefully the lights won't be from you passing out from boredom and boinking your head on the keyboard. You are going to use a lot of code in this series that will have stuff in it that you won't understand (yet).



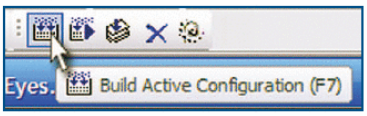
■ FIGURE 6. Project Options.

■ FIGURE 5. Project Configuration Options.



My reasoning is that by jumping into the deep end, you get to do some interesting things now and you can learn how things work later. Keep this in mind if you don't understand all of what we are doing here. Eventually, you'll see an explanation or at least become more comfortable with mystery — a trait all programmers develop over time. In the AVR Studio IDE center screen, you'll see a text window titled: 'C:\Workshop\CylonEyes.c'. Either type what is shown in Listing 1 or download it from the files that are included on the *Nuts & Volts* website (**www.nutsvolts.com**). Press the 'Build Active Configuration' button (Figure 7). This will generate CylonEyes.hex.

■ FIGURE 7. Build Active Configuration.



A Brief Introduction to C — What Makes CylonEyes Blink Those LEDs?

This section takes a very brief look at CylonEyes.c to help begin understanding what each line means. Later, these items will be covered in greater detail in the context of programs written specifically to aid in learning the C programming language, as it is used for common microcontroller applications.

Comments

You can add comments (text the compiler ignores) to your code two ways. For a single line of comments, use double back slashes as in

```
// CylonEyes.c
```

For multi-line comments, begin them with /* and end them with */.

Include Files

```
#include <avr/io.h>
#define F_CPU 10000001
#include <util/delay.h>
```

The '#include' is a preprocessor directive that instructs the compiler to find the file in the <> brackets and tack it on at the head of the file you are about to compile. The io.h provides data for the port we use, and the delay.h provides the definitions for the delay function we call. The #define F_CPU 1000000l is placed before the delay.h include since that file requires a value for F_CPU in order to create a timed delay.

Operators

Operators are symbols that tell the compiler to do things such as set one variable equal to another, the '=' operator, as in 'DDRB = 0xFF,' or the '++' operator for adding 1, as in 'counter++.'

Listing 1

```
// CylonEyes.c
#include <avr/io.h>

// The last character is a lower case 'L' not a 1 (one)
#define F_CPU 10000001

#include <util/delay.h>

int main (void)
{
   int i = 0;

   // set PORTD for output
   DDRD = 0xFF;

      while(1) {
            for(i = 1; i < 128; i = i*2)
            {
               PORTD = i;
               _delay_loop_2(30000);
            }

            for(i = 128; i > 1; i -= i/2)
            {
               PORTD = i;
               _delay_loop_2(30000);
            }
      }
      return 1;
}
```

Download CylonEyes to the Butterfly

In Workshop 1, you hooked the Butterfly to a RS-232 cable and downloaded your name. Hook it up again and access the Butterfly bootloader by turning the Butterfly off, then pressing the joystick button to the center, and holding it pressed while turning the Butterfly back on.

Back to the AVR Studio ... Open the Tools menu and **WHILE JOYSTICK BUTTON PRESSED**, click the 'AVR Prog...' menu item. In the AVRProg window, browse to find the CylonEyes.hex file. Click on the 'Flash' 'Program' button. You should see the progress bar zip along and AVRProg will say: 'Erasing Programming Verifying OK.'

■ FIGURE 8. AVR Prog.

■ FIGURE 9

If instead of the window shown in Figure 8, you get the dreaded 'No supported board found' window shown in Figure 9, then you will need to look at the *'Using AVRProg with the AVR Butterfly'* pdf file in the Workshop 2 downloads at **www.nutsvolts.com** and **www.smileymicros.com**. Don't feel too bad, lots of folks have trouble getting over this hurdle, but once you get it working it is smooth sailing from here on out. (Okay, that's a lie; this stuff is always hard. So be careful, patient, and persistent.)

Expressions, Statements, and Blocks

Expressions are combinations of variables, operators, and function calls that produce a single value. For example:

```
PORTD = 0xFF - counter++
```

This is an expression that sets the voltage on pins on port D to +3V or 0V based on the value of the variable 'counter' subtracted from 0xFF (a hex number — we'll learn about these and ports later). Afterwards, the counter is incremented.

Statements control the program flow and consist of keywords, expressions, and other statements. A semicolon ends a statement. For example:

```
TempInCelsius = 5 * (TempInFahrenheit-32)/9;
```

This is a statement that could prove useful if the Butterfly's temperature readings are derived in Fahrenheit but the user wants to report them in Celsius.

Blocks are compound statements grouped by open and close braces: { }. For example:

```
for(i = 1; i < 128; i = i*2)
{
      PORTD = ~i;
      _delay_loop_2(30000);
}
```

This groups the two inner statements to be run, depending on the condition of the 'for' statement which will be explained next.

Flow Control

Flow control statements dictate the order in which a series of actions are performed. For example: 'for' causes the program to repeat a block. In CylonEyes, we have:

```
for(i = 1; i < 128; i = i*2)
{
      // Do something
}
```

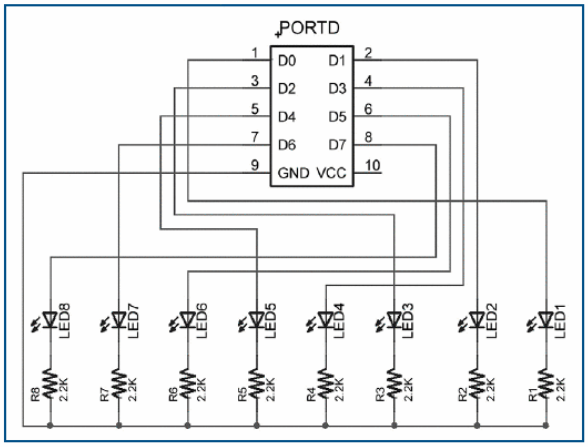
Building CylonEyes Hardware

We built the AVR Workshop Learning Platform in the last workshop. Details for the construction can be found in: *Smiley's Workshop 1 Supplement: AVR Learning Platform Foamcore Base and Box* also available on the websites. Follow the schematic in Figure 10 and photo in Figure 11. If you haven't done this before, please refer to the supplement: *Using a Breadboard* included in the downloads. Cycle the power. The LCD will be blank. Click the joystick up and your LEDs should be making like a Cylon's eyes with the light moving back and forth. Cool, huh?

NOTE: *The Butterfly LCD dances like crazy with each LED message pass because some of the port D pins are also tied to the LCD. Will it harm the LCD? Probably not, but I don't know for sure, so don't leave CylonEyes running overnight.*

When you compile CylonEyes.c, you may suspect that a lot of stuff is going on in the background, and you would be right. Fortunately for us, we don't really need to know how it does what it does. We only need to know how to coax it to do what we need it to do: convert

■ FIGURE 10. CylonEyes schematic.



On the first pass, the code evaluates the 'for' statement, notes that variable 'i' is equal to 1 which is less than 128, and runs the block of 'Do something' code. Next, the 'for' expression is reevaluated with 'i' now multiplied by 2 'i = i*2' which is 2 and 2 < 128 is true, so the block runs again. Next, i = 4, and so on till i = 128, and '128 < 128' is false. The program stops running the loop and goes to the next statement following the closing bracket.

Quick now, how many times does this loop run? The series of 'i' values evaluated against the '< 128' is '1,2,4,8,16,32,64,128' and since it takes the 128 as the cue to quit, the loop runs eight times.

The while('expression') statement tests the expression to see if it is true (meaning that it is not equal to 0, which is defined as false) and allows the block to run if true. After running through the loop, it retests the 'expression,' looping through the block each time it is true. The program proceeds to the next statement when the expression becomes false.

```
int 1 = 0;
while(i < 10)
{
      // load the x array with the y array
      x[i] = y[i++];
}
```

The 'while' loop runs 10 times since the 'i' is incremented (has 1 added to the current value) 10 times, putting the first 10 values of the y array into the x array — more on arrays later.

A while(1) runs the loop forever because '1' is true (false is 0). We use this to keep the 'main' function from exiting.

Functions

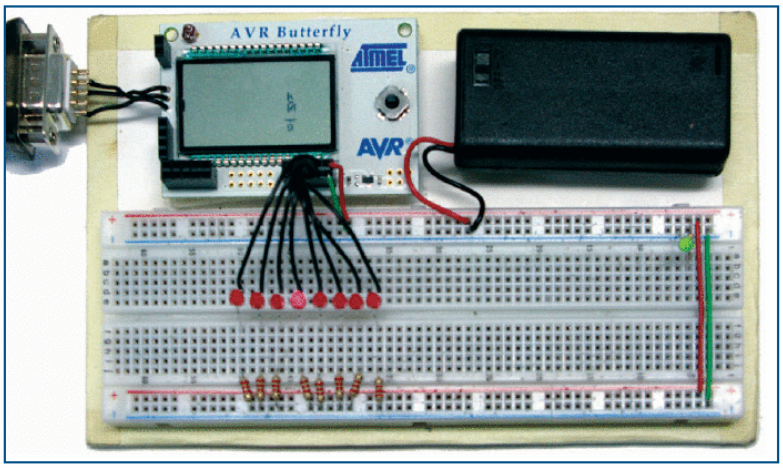
A *function* encapsulates a computation. Think of them as building material for C programs. A house might be built of studs, nails, and panels. The architect knows that all 2x4 studs are the same, as are each of the nails and each of the panels, so there is no need to worry about how to make a 2x4 or a nail or a panel; you just stick them where needed and don't worry how they were made. In the CylonEyes program, the main() function uses the _delay_loop_2() function twice. The writer of the main() function doesn't need to know *how* the _delay_loop_2(30000) function does its job, he only needs to know *what* it does and what parameters to use, in this case, 30000 will cause a delay of about 1/8 second.

The _delay_loop_2() function is declared in the header delay.h and the AVRStudio is set up so that the compiler knows where to look for it.

Encapsulation of code in functions is a key idea in C programming and helps make chunks of code more convenient to use. And just as important, it provides a way to make tested code reusable without having to rewrite it. The idea of function encapsulation is so important in software engineering that the C++ language was developed primarily to formalize these and related concepts and force their use.

CylonEyes.c into CylonEyes.hex. If you raise the hood on WinAVR, you would see a massively complex set of software that has been created over the years by folks involved in the open software movement.

When you have questions about WinAVR — and you will — check out the forums at **www.AVRFreaks.net**, especially the GCC forum, since WinAVR uses GCC to compile the C software. Try searching the forums before asking questions since someone has probably already asked your question and received good responses. Forum helpers tend to get annoyed with newbies who don't do sufficient background research before asking questions.



■ FIGURE 11. Base board with CylonEyes.

Joe Pardue (**nv@smileymicros.com**) has a BSEE and operates **www.smileymicros.com** from the shadows of the Great Smokey Mountains in Tennessee. He is author of *Virtual Serial Port Cookbook* and *C Programming for Microcontrollers*.

The Main() Thing

All C programs must have a 'main' function that contains the code that is first run when the program begins.

```
int main (void)
{
// Do something
}
```

Listing 2 shows what CylonEyes has. In this function, we leave C for a moment and look at things that are specific to the AVR microcontroller. The line:

```
DDRD = 0xFF;
```

sets the microcontroller Data Direction Register D to equal 0xFF. This tells the microcontroller that port D pins, which are hooked up to our LEDs, are to be used to output voltage states (which we use to turn the LEDs on and off). We use the hexadecimal version, 0xFF, of 255 here because it is easier to understand what's happening. You disagree? Well, if you persist with these workshops, you'll be using hexadecimal numbers like a pro and understand they do make working with microcontrollers easier, but for now, just humor me. The program tests the while(1) and finding it true, proceeds to the 'for' statement, which is also true and passes to the line:

```
PORTD = i;
```

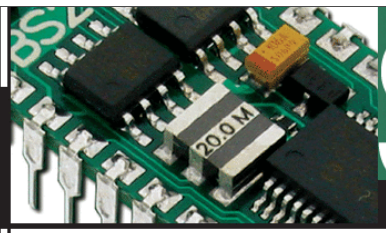
This causes the microcontroller to set the port D pins to light up the LEDs with the pattern made by the value of i.

Say what? Okay, 'i' starts off equal to 1, which in binary is 00000001. This provides +3V on the rightmost LED, and leaves the other LEDs unlit at 0V.

The first 'for' loop runs eight times, each time moving the lit LED to the left, then it exits. In the next 'for' loop, the -= operator subtracts i/2 from i and sets i equal to the results causing the LED to move to the right. When it is finished, the loop runs again ... for how long? Right! Forever! Or at least until either the universe ends or you unplug the Butterfly. We skimmed over a lot that you'll see in detail in later workshops. You now know just enough to be dangerous and I hope the learning process hasn't caused your forehead to do too much damage to your keyboard. **NV**

Listing 2

```
int main (void)
{
    int i = 0;
    // set PORTD for output
    DDRD = 0xFF;

    while(1)
    {
        for(i = 1; i < 128; i = i*2)
        {
            PORTD = i;
            _delay_loop_2(30000);
        }

        for(i = 128; i > 1; i -= i/2)
        {
            PORTD = i;
            _delay_loop_2(30000);
        }
    }
}
```



■ BY JON WILLIAMS

EXPERIMENTS WITH SOUND

IT WOULD BE MORE THAN FAIR TO SAY THAT I'M A LIGHT SLEEPER. To be honest, I don't think that I have ever slept for more than a couple hours at a stretch. Don't get me wrong, I tie a few of those stretches together each night (well, most nights) so that I'm rested in the morning, but I'm certain that I have never slept all the way through the night. I'm not talking about tossing and turning, mind you, I'm talking about full wake-up — usually at the end of a vivid dream or nightmare. A friend had told me that she can tell her husband to be quiet when he is snoring or talking in his sleep and he will obey. Well, I don't have a wife or girlfriend, so I guess I'll just turn to technology. How sad am I?

Well, not too sad, thankfully, as I have many wonderful friends. One of those friends is a guy you Halloween enthusiasts have probably heard of — "Scary" Terry Simmons. Let me just say for the record that he is anything but scary; Terry is one of the nicest people I've ever known, and having been a guest in his home on several occasions, I can say that with some authority.

A couple months ago, Terry asked for a bit of help with the Vinculum VMUSIC2 MP3 player. I'd seen it, but hadn't really paid much attention to it until Terry thought he'd give it a go with the BS1, the BS2, and even the SX. So, I bought one and found that it's really kind of neat — my experiments with it and its quirks are going to be the focus here. No PCB to worry about for this article, we're just going to play. Just a VMUSIC2, a USB memory stick, and your favorite SX prototyping setup is all you'll need.

So, getting back to the sleep thing, what I'm going to do is put together a little circuit — albeit temporary until it proves — that will play audio while I'm sleeping to keep me from waking up. Perhaps I'll plant some suggestions in the audio to help me achieve my personal goals; a sleeping hypnosis device — that's it, we'll call it Sleepnotizer!

VMUSIC2

The VMUSIC2 is a little demonstration unit that allows you to play MP3 audio files from a USB memory stick. It is easily controlled through a serial or SPI type interface — we're going to use serial as it seems the most straightforward. When using serial mode, the VMUSIC2 is typically configured to accept text commands as if one was sending them from a terminal. So making the thing work is actually pretty simple. What I did was go through an instruction set and create SX/B subroutines and functions that encapsulated the various features.

To give you an idea how easy the device is to use, we could play a file called firefly.mp3 with a couple of standardized subroutines:

```
TX_STR  "VPF firefly.mp3"
TX_BYTE CR
```

What we'll do, of course, is wrap this code into a nice subroutine where all we have to do is pass the name of the file (without extension).

GOING WITH THE FLOW

Looking at the VMUSIC2 connections, you'll see that it typically exerts hardware flow control. This means it will bring its RTS line low when its buffer has available space and it will stop transmitting when its CTS input goes high — this would signal that our receive buffer is presently full.

Adding flow control to the VP UARTS we've used in previous projects turned out to be trivial — here's what it looks like on the receive end:

```
Receive:
  ASM
    BANK  rxSerial
    JB    rxBufCnt.4, RX_Done
    MOVB  C, RX
    TEST  rxCount
    JNZ   RX_Bit
    MOV   W, #9
    SC
     MOV  rxCount, W
    MOV   rxDivide, #Baud1x5

RX_Bit:
```

```
    DJNZ   rxDivide, RX_Done
    MOV    rxDivide, #Baud1x0
    DEC    rxCount
    SZ
     RR    rxByte
    SZ
    JMP    RX_Done

RX_Buffer:
    MOV    W, #rxBuf
    ADD    W, rxHead
    MOV    FSR, W
    MOV    IND, rxByte
    INC    rxHead
    CLRB   rxHead.3
    INC    rxBufCnt
    SETB   rxReady

Update_CTS:
    MOVB   rxBufCnt.3, CTS

RX_Done:
    BANK   $00
  ENDASM
```

Note the section called **Update_CTS** near the end of this module — just one line of assembly takes care of the CTS. What it's doing is copying the value of bit 3 of *rxBufCnt* to the CTS pin. We do this because the buffer, has a maximum capacity of eight bytes; when we have eight bytes in the buffer bit 3 of *rxBufCnt* will be high and placing a high on the CTS line with cause the external device (VMUSIC2, in this case) to stop transmitting when it is configured for RTS/CTS hardware control.

Updating the transmit UART is equally simple: We just abort the actual transmit section of the UART when the RTS pin goes high. You'll see that in the listing.

I tested the hardware flow control UARTs with a HyperTerminal and then proceeded to move forward with the VMUSIC2 player. That's when things came to a big, screeching halt.

In Terry's experiments with the VMUSIC2 player, he simply wired the CTS input low so that the unit could send data any time it wanted to. This works with the BASIC Stamp because the serial input is ignored unless sitting on a **SERIN** line. When using a buffered UART, we could easily have an overrun situation as the VMUSIC2 transmits position data as it's playing.

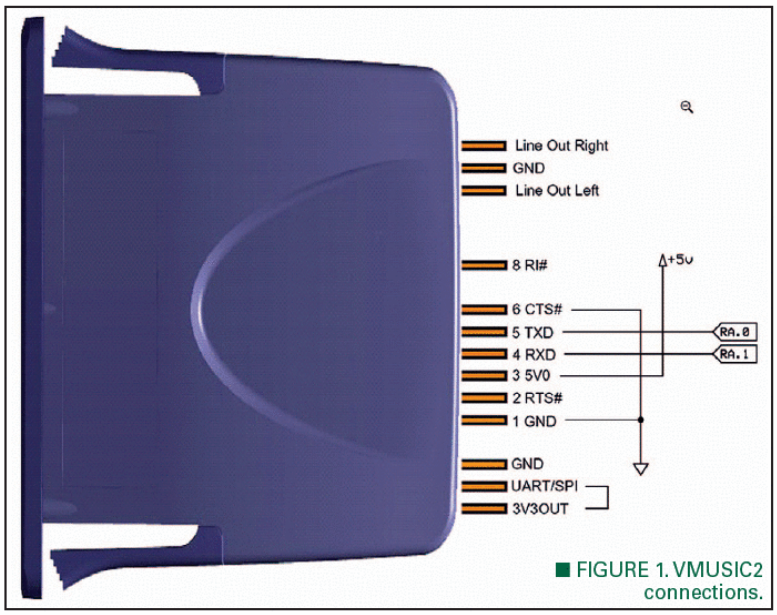
Let me just cut right to the chase — after a day and a half of experimenting, I abandoned the idea of using flow control with the VMUSIC2 player and went to simple, non-interrupt code — BASIC Stamp-style, if you will. The reason for this is that when the CTS goes high (our buffer is full), the VMUSIC2 stops playing! This is not good and not worth the trouble to deal with. In the end, I have working code that gives my VP UARTs hardware flow control, but I've decided against using this code with the VMUSIC2 player (non flow control code is fine). I will include the flow control UART code in the download file (go to **www.nutsvolts.com**) so that you can use it with other projects.

PLAY THE MUSIC

One of the great features of the VMUSIC2 player is that you can reconfigure its baud rate by changing a file on the memory stick. Terry has saved us the trouble of creating these files and has two versions on his website (see references): one for the BASIC Stamp 1 that operates at 2400 baud; another for the BASIC Stamp 2 that operates at 9600. While we could crank up the baud rate for the SX, 9600 is fine as there's not a lot of traffic and that will let us move the VMUSIC2 player between the SX and BASIC Stamp 2 without updating the firmware file.

So, before you get started you'll need to copy the file called **ftrfb_9600.ftd** to a memory stick, rename it **ftrfb.ftd**, plug the stick into the player, and then apply power. On the first power-up with this new firmware file, it will be loaded into the VMUSIC2 player and will configure it for 9600 baud ASCII input.

Okay, now, let's play a file. Figure 1 illustrates the connections to the VMUSIC2 player — which turn out to be just exactly like Terry's. Here's the rub: The pin headers on the back of the VMUSIC2 player are space at 2 mm instead of the 2.54 mm (0.1 inch) like we're used to. The player does come with a short female-female cable, but the pin spacing makes it useful on only one end. I cut off one of the connectors and soldered male crimp pins to the ends — this lets me prototype with the VMUSIC2 using any of my standard development boards (e.g., Parallax Professional development boards). Figures 2 and 3



■ FIGURE 1. VMUSIC2 connections.

show the unmodified and modified cables.

Once we've got things connected, the rest comes pretty easy, though I did find a couple traps along the way. Let's start with simple playback.

```
SUB VM_PLAY
  tmpW2         = __WPARAM12

  TX_STR  "VPF "
  TX_STR  tmpW2
  TX_STR  ".MP3"
  TX_BYTE CR
  isPaused = No
  ENDSUB
```

With **VM_PLAY,** we send an inline file name (without the .mp3 extension) or a label that has a z-string with the file name. **TX_STR** and **TX_BYTE** take care of sending the name, extension, and a carriage return to the player. I've included a flag in the program that keeps track of the paused state of the device, so this gets cleared on a new play command. Keep in mind that if you send one play command while another file is playing, the original file will be stopped and the new one will play.

And speaking of stopping ... the VMUSIC2 player has just one processor that handles serial I/O with its host (the SX, in our case) and pulling data from the USB memory stick to send to the MP3 decoder. So, if you send any command when a file is playing this can interrupt the audio output. I bring this up because there are commands that we may want to send while a file is playing, specifically volume control.

```
SUB VM_VOLUME
  tmpB3 = __PARAM1

  tmpB3 = tmpB3 MAX $FE

  TX_STR "VSV $"
  TX_HEX2 tmpB3
  TX_BYTE CR
  ENDSUB
```

The **VM_VOLUME** subroutine takes care of setting the output volume of the VMUSIC2 player. It seems a little odd at first that we use zero for the loudest volume; what we're actually setting inside the player is the attenuation from maximum loudness. Note, too, that the player sets the left and right channels to the same level. In order to simplify the SX code, we're sending numeric values to the player in indicated hex ($) mode; this is done using the **TX_HEX2** subroutine.

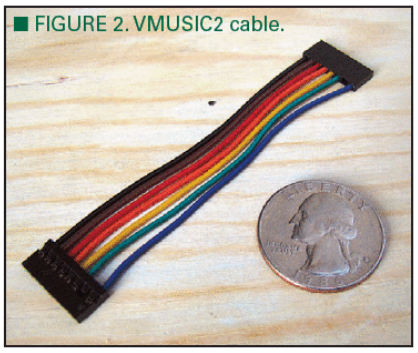
What happens if we want to move the sound from one side to the other? There is no easy command in the VMUSIC2 command set to do this, but there is an advanced command that lets us write to registers inside the MP3 decoder. We must be very careful when doing this — my VMUSIC2 made some really interesting and really awful noises when I started experimenting with direct register control.

```
SUB VM_PAN
  tmpB3 = __PARAM1
  tmpB4 = __PARAM2

  tmpB3 = tmpB3 MAX $FE
  tmpB4 = tmpB4 MAX $FE

  TX_STR "VWR $0B"
  TX_HEX2 tmpB4
  TX_HEX2 tmpB3
  TX_BYTE CR
  ENDSUB
```

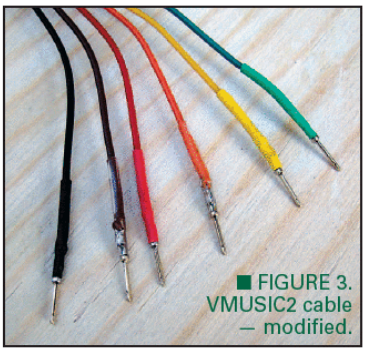
I've created a subroutine called **VM_PAN** that expects levels for the left and right channels to be passed to it, then writes those levels directly to the MP3 decoder chip. It does this with the VWR (write to register) command; the target is register $0B which is a 16-bit value holding the channel levels. The tricky bit with the **VM_PAN** routine is that its settings get wiped out by a play command — this is something that the VMUSIC2 firmware does.

So, if we want to play a file from only one side, for example, what we actually have to do is start the file and then immediately call the **VM_PAN** subroutine to move the audio as required. Unfortunately, if we do call **VM_PAN** in the middle of audio, there may be a little "click" in the audio output; this will depend on what's in the MP3 decoder buffer — and this is where one could make an argument for a higher baud rate to minimize the communications time to the VMUSIC2.

Vinculum supplies a program called **VncFwMod.exe** that can be used to update the firmware file which is where we change the baud rate. This program is available on the Downloads page of the Vinculum site and is listed as Vinculum Firmware Customizer. I actually keep a copy of this on my memory stick so that I can plug the stick into my computer at any time and update the firmware file. It's a good idea to use a different revision code when you change the firmware, and do remember that you need to cycle power to the VMUSIC2 for updated firmware to be loaded.



■ FIGURE 2. VMUSIC2 cable.



■ FIGURE 3. VMUSIC2 cable — modified.

EXPERIMENTING ON MYSELF

Let's wrap up the Sleepnotizer as this puts the VMUSIC2 code to use.

```
Start:
  PLP_A = %0011
  PLP_B = %1000_0001
  PLP_C = %0000_0000

  TX = 1
  OUTPUT TX
  DELAY_MS 1

  DELAY_MS 2500
  TX_BYTE CR
  VM_WAIT_PROMPT

  VM_STOP
  VM_WAIT_PROMPT

  VM_VOLUME $00
  VM_WAIT_PROMPT
```

As always, the pull-ups are enabled for unused pins; this minimizes current consumption. Then, a 1 is written to the TX line and it's made an output. The reason to do it in this order is to prevent creating a false start bit; if the pin is made an output before having the 1 written to it, this will look like a start bit to the VMUSIC2 player

A two-and-half second delay is inserted to allow the VMUSIC2 player to power up. Then we "ping" the player by sending a carriage return and waiting on the ">" prompt as this lets us know that the player is ready. The code for **VM_WAIT_PROMPT** is straightforward; it sits in a loop waiting for the prompt character:

```
SUB VM_WAIT_PROMPT
  DO
    tmpB1 = RX_BYTE
  LOOP UNTIL tmpB1 = ">"
  ENDSUB
```

If the SX was reset after a power-up, there is the possibility that a file is playing so we can kill it with **VM_STOP**. Then, we reset the volume to the highest level and drop into the heart of the program.

I added a simple pushbutton and LED to an SX Tech board to provide the interface for my little experiment. After power-up, the program waits for the button to be pressed and stirs a random number that will be used later.

```
Main:
  seed = RANDOMIZE seed
  IF StartBtn = NotPressed THEN Main
```

The SX/B **RANDOM** function uses different algorithms for bytes and words, so I wrapped **RANDOM** into a unified function that looks like this:

```
FUNC RANDOMIZE
  IF __PARAMCNT = 1 THEN
    tmpW1 = __PARAM1
    RANDOM tmpW1_LSB
  ELSE
    tmpW1 = __WPARAM12
    RANDOM tmpW1
  ENDIF
  RETURN tmpW1
  ENDFUNC
```

If a byte gets passed to the function, then that value is moved into *tmpW1* and the **RANDOM** function is used only on the LSB. When a word is passed, both bytes are used. You can see the difference in how **RANDOM** is handled by the compiler by looking at the List file (Ctrl-L in the IDE). The function does, in fact, return two bytes, but when the target is a byte variable only the LSB is used.

```
Induction_Delay:
  FOR seconds = 1 TO 120
    FOR tix = 1 TO 10
      Led = tix.0
      DELAY_MS 100
    NEXT
    seed = RANDOMIZE seed
  NEXT

Induction:
  VM_PLAY "induce"
  VM_WAIT_START
  Led = IsOn
  VM_WAIT_PROMPT
```

After the button is pressed, there is a two-minute delay before the sleep induction file is played. Within a loop that handles the delay, another loop creates a one second delay. I did this so that I could flash the LED at a 10 Hz rate while doing the delay.

Once the **VM_PLAY** command is issued, we may want to verify that the player has actually started; we can do this with **VM_WAIT_START**. This function watches the RX line waiting on a specific string that indicates the start of the audio — what we're actually looking for is a time position indicator which is a string that starts with "T $."

```
SUB VM_WAIT_START
  tmpB1 = RX_BYTE ToUpper
  IF tmpB1 <> "T" THEN VM_WAIT_START
  tmpB1 = RX_BYTE
  IF tmpB1 <> " " THEN VM_WAIT_START
  tmpB1 = RX_BYTE
  IF tmpB1 <> "$" THEN VM_WAIT_START
  ENDSUB
```

Finally, the program drops into a loop that inserts about a 90 minute (plus or minus five minutes) delay before playing the sleep file. The loop runs three times which should get me through most of my normal sleep cycle.

```
Sleepnotize_Me:
  FOR cycles = 1 TO 3
    seed = RANDOMIZE seed
    seconds = seed // 601
    seconds = seconds + 5100
    DO WHILE seconds > 0
      FOR tix = 1 TO 10
        Led = tix.0
        DELAY_MS 100
      NEXT
      DEC seconds
      seed = RANDOMIZE seed
    LOOP
    VM_PLAY "sleep"
    VM_WAIT_START
    Led = IsOn
    VM_WAIT_PROMPT
  NEXT

  Led = IsOff
  GOTO Main
```

PARTS LIST

Item	Supplier/Part No.
VMUSIC2	Mouser/895-VMUSIC2
Male Crimp Terminal	Mouser/538-16-02-0114
SX Tech Board	Parallax/45205

Just a reminder on using the modulus operator: When we do a modulus, the result will be somewhere between zero and the divisor minus one. In this case, I wanted to create a random 10 minute time frame; 10 minutes is 600 seconds, so using 601 gets us there when using modulus. By adding this result to 5,100 (85 minutes), the final result is somewhere between 85 and 95 minutes.

And that does it for the Sleepnotizer. Who knows how long I'll leave this thing hooked up, but if it works then I might build a permanent version. And no matter what, now we've got a nice library of VMUSIC2 routines that let us add MP3 audio to any of our SX projects.

BRAKE LIGHT BUDDY UPDATE

So far, so good — I haven't been smashed into. And despite a new law in California that forbids using one's phone in the car without a hands-free device, people still charge down the 405 in full-force conversation with phones held to their ear. I have found that the Brake Light Buddy (BLB) is especially effective at night, probably because my vanity license plate (EFX-TEK) and Screen Actors Guild plate frame are less obvious. A friend was following me one evening and said that it definitely got his attention.

Not long after I installed my BLB, I happened to come out of a convenience store and found a Burbank police car parked next to my SUV. I approached the officer and asked if he could help me check my brake lights. He cheerfully accommodated, and when I pressed the brake pedal he got a slightly peculiar look on his face. When I asked him if it was legal, he said that it was. Then I asked him to do one more check and I switched the pattern to the one that flashes like a police light bar. Well, the look didn't get any better — in fact, he shook his head a bit — but admitted that it was still legal.

A couple of the points I speculated on turned out to be true. The BLB is okay in California as I installed it because:

1) The lights are all red; different colors would have generated a ticket.

2) The device points backward; pointing it forward is a big no-no.

So, if you live in California I believe you're okay to go. Please, if you live elsewhere then you should check your local vehicle code. (Yeah, right, who does that? Nobody, of course.) I suggest you consult a local police officer on the legal aspects of using the BLB in your area.

SX/B – TWO POINT OH!

Next time, we'll get into SX/B 2.0; compiler engineer "Bean" worked very hard to update SX/B and has packed some great new stuff into this version. We've come a long way since SX/B's release nearly four years ago, and things just keep getting better and better and better — and it's still free!

Until next time then, Happy Stamping, SX-style. **NV**

JON WILLIAMS
jwilliams@efx-tek.com

RESOURCES

PARALLAX, INC.
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SCARY TERRY VMUSIC2 INFO (FOR BS1 AND BS2)
www.scary-terry.com/vm2/vm2.htm

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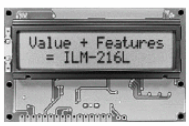

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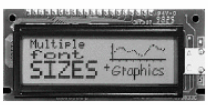

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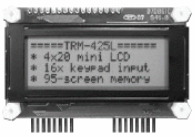

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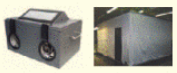

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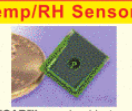

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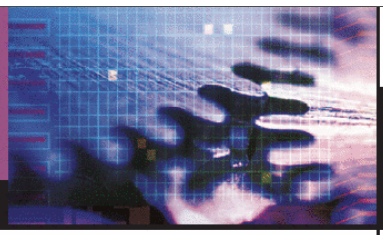


■ BY FRED EADY

ROLL YOUR OWN FPGA DESIGN

TO REALLY GET TO KNOW A MICROCONTROLLER, CPLD, OR FPGA, one may take the programming and hardware design knowledge gleaned from a factory-generated development kit and apply it to a unique personal application. We've paid our dues with a factory Xilinx FPGA development board. So, our goal this month is to get down and dirty with our own Xilinx XC3S50A FPGA design.

For the past 60 days or so, I've been glued to the XC3S50A datasheet and user's guide. In that time, I've come to terms with what it takes to put an FPGA like this to work from the hardware and firmware perspectives. I'm going to show you how to take the bare home-brewed 50A development board you see in Photo 1 from concept to reality. To best understand the 50A and its supporting components, I'll break the FPGA hardware and firmware into smaller modules that can be easily digested and understood. A good place to start is with the power supply.

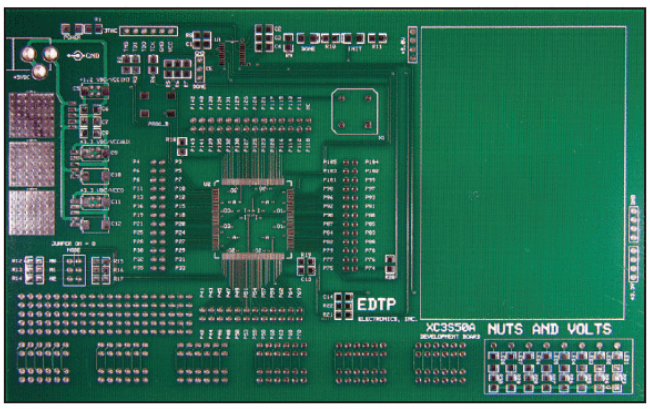
POWERING UP THE XC3S50A

The XC3S50A operates with a trio of power supply voltages. The hardware core requires a regulated 1.2 volt power source. A separate VCCAUX power supply voltage is used to drive the JTAG interface. For the Spartan-3A devices, VCCAUX voltage levels can be implemented as either 2.5 or 3.3 volts. With JTAG hardware, things get easier when we choose to power the 50A's VCCAUX pins with 3.3 volts. The I/O pins are driven by the VCCO power rail. For the purposes of our design, all of our I/O will be 3.3 volt compatible. Thus, the VCCO power supply will be designed to provide 3.3 volts.

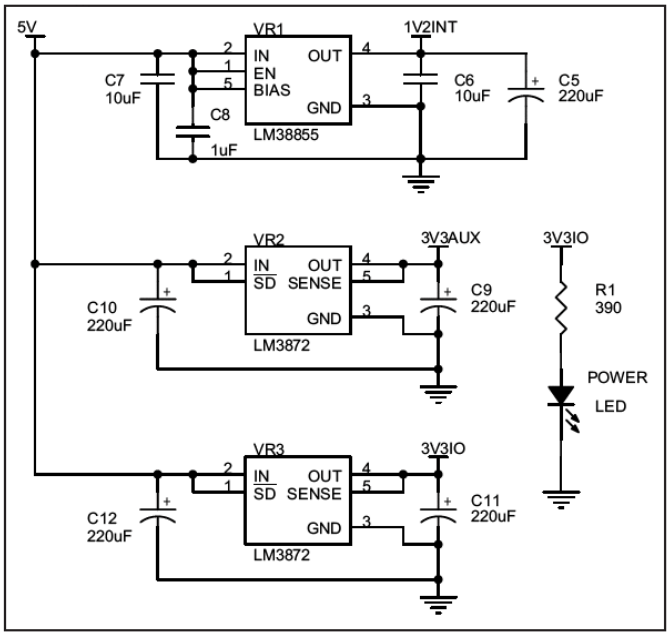
I wanted to keep the power supply as simple as possible. At the same time, I also wanted to design in a power supply system with components that are intended for use with an FPGA. That means I will avoid using run-of-the-mill 7805 and LM317 circuits. The LDO (low dropout) voltage regulators I've outlined in Schematic 1 are intended to be used in battery-powered applications, which may include FPGAs and microcontrollers. As you can see in the power supply schematic, all of the LDO voltage regulators require a minimum of external components.

The LP38855 provides the FPGA's 1.2 volt core supply voltage. Being available in standard voltages of 0.8 and 1.2 volts puts the LP38855 squarely into the FPGA application arena. It can supply up to 1.5 amperes of current and only requires 10 µF ceramic capacitors on its input and output pins. The key to a stable LP38855 design lies in the selection of the input and output capacitors. The 10 µF, X7R ceramic capacitors are required for stability. However, once they are in place, we can hang unlimited additional capacitance on the LP38855's input and output pins in parallel with the ceramic capacitors. I chose to add a 220 µF tantalum output capacitor to my 1.2 volt design. In addition to the 10 µF ceramic input and output capacitors, the regulator also requires a good quality 1 µF capacitor between its BIAS pin and ground.

Since the LP38855 datasheet recommended a ceramic BIAS capacitor, I designed in an X7R 1.0 µF ceramic capacitor. Note that the ENABLE pin is tied to the BIAS and INPUT pins since we don't have a need to disable the output. The LP38855 variant I used in this



■ PHOTO 1. Putting down the project parts won't be as difficult as it may seem from this perspective. The only "tight" soldering that we will have to do is performed on the Platform Flash IC. Even with that, we can still hand–solder every part on the board.



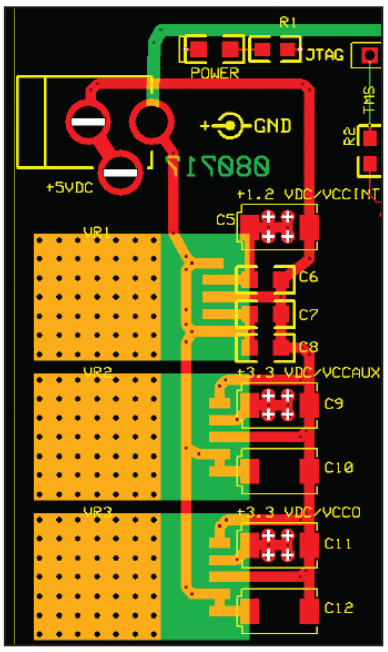
■ SCHEMATIC 1. On paper, it doesn't get much simpler than this. However, on the PCB, the geometry of the copper layout is very important as it directly affects the stability of the XC3S50A power supply system as a whole.

design is formally specified as "-1.2" part, which is the 1.2 volt version in a TO-263 package.

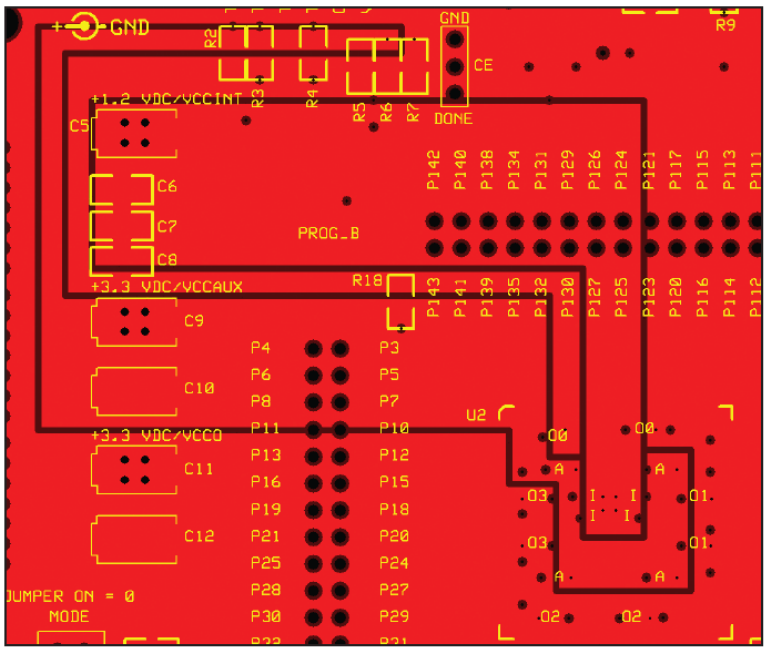
The remaining XC3S50A 3.3 volt power rails are generated using an LP3872. If you're wondering why I didn't use an LP3872 for the 1.2 volt power rail, the answer can be found in the datasheet. The minimum regulated voltage that the LP3872 can supply is 1.8 volts; 1.8 volts is great for a CoolRunner-II CPLD's core but is just a tad high for our XC3S50A FPGA core. Like the LP38855, the LP3872 is just as picky about its capacitor complement. A minimum of 10 µF is required on the LP3872's input and output pins. Its input and output capacitors can be tantalum, ceramic, or electrolytic as long as their ESR (equivalent series resistance) values fall into the LP3872's specifications. Tantalum capacitors are recommended by its datasheet. So, guess what? I dropped in a couple of 220 µF tantalums for each 3.3 volt LP3872 LDO voltage regulator. They can source up to 1.5 amperes and come with bells and whistles that we won't use in our design this time. As you can see in Schematic 1, I disabled the SHUTDOWN (SD) and ERROR/SENSE (SENSE) features of the LP3872.

The LP3872 suggests that certain layout rules be followed to insure the stability of the power supply circuit. Its output capacitors should all lie within 1 cm of the

■ SCREENSHOT 1. The LP3872 wants the output capacitors within 1 cm of the output pin. In addition, vias and internal copper planes are frowned upon and should not be used to connect the output capacitors to the LP3872 output pin.



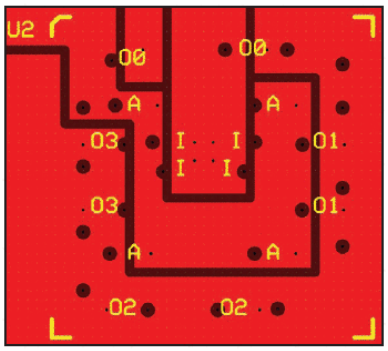
■ SCREENSHOT 2. The ExpressPCB printed circuit board layout application allows us to partition the ground and power planes. Here, I've isolated the VCCINT, VCCAUX, and VCCO voltages and routed them to their FPGA and JTAG destinations.



voltage regulator. In addition, vias and any other indirect means of connecting the output capacitors to the LP3872 output pin is taboo. You can see how I followed the rules by examining the printed circuit board (PCB) top copper layout of the voltage regulators and their associated capacitors in Screenshot 1. All of the voltage regulator input and output capacitor hardware interconnects are large direct copper paths that tie directly to the pins of their associated voltage regulators. I also carried the LP3872 PCB layout rules over to the LP38855 circuitry.

Vias are only used to transfer the output voltages to the internal voltage planes within the four-layer ExpressPCB printed circuit board. I've isolated the three PCB power planes in Screenshot 2. Note that I positioned each quad of voltage regulator output vias to feed their respective power plane partitions. The silkscreen in Screenshot 3 zeroes in on the locations of the vias that are feeding the XC3S50A power pins. A total of four VCCINT pins are fed from the power plane partition and are marked with an "I." There are also four VCCAUX power inputs. You can get an idea of where they are as they are marked with an "A." All of the XC3S50A I/O banks are powered by the VCCO partition. There are two power inputs per bank. I've identified the VCCO power points with numbers that represent the banks (00,01,02,03) that are being fed by vias located within that power partition.

The voltage regulators are all fed from a common 5.0 volt source. I used a regulated wall wart to supply the bulk 5.0 volts. There are a couple of reasons I chose to drive the XC3S50A power supply with 5.0 volts. Some peripherals that I would like to drive with its require a



■ SCREENSHOT 3. The large dots are ground plane connections and are "no connects" to the power plane. There are smaller dots next to each of the silkscreen legends that are, in reality, the vias that are taking power from the planes to the XC3S50A power pins.

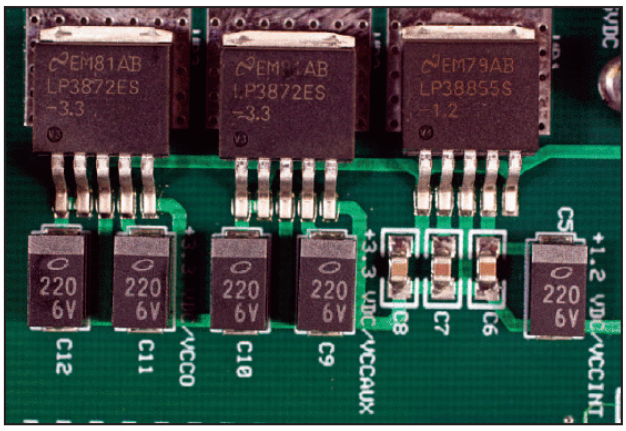
5.0 volt power rail. One good example of this peripheral is an industry standard 16 x 1 LCD module. The other reason I selected a bulk input voltage of 5.0 volts is that the LP38855 can only tolerate up to 5.5 volts on its input. I decided to exclude the 5.0 volt bulk input voltage from the PCB power plane. Instead, I designed in a 5.0 volt header next to the solderless breadboard that I feed with a trace on the solder side of the PCB.

The XC3S50A power supply voltage regulator components come together as shown in Photo 2. As you can see in this photo, the 3.3 volt LP3872 voltage regulators are also packaged in a TO-263 form factor and are specified as LP3872ES-3.3. No logic power supply system is complete without power bypass capacitors. I mounted the 0603 FPGA bypass capacitors on the solder side of the PCB (as shown in Photo 3) to keep things tidy on the component side of the PCB. The XC3S50A power supply bypass capacitors and their associated power pins are broken out for you in Schematic 2.

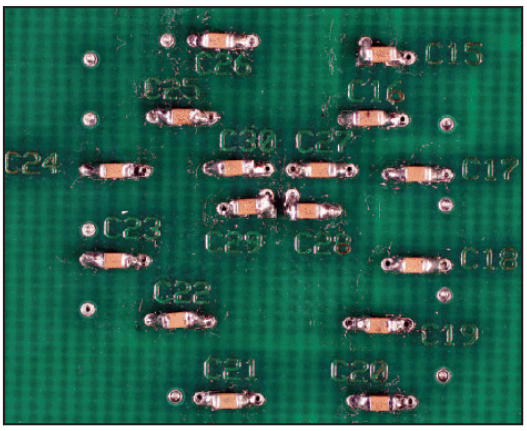
PROGRAMMING THE XC3S50A

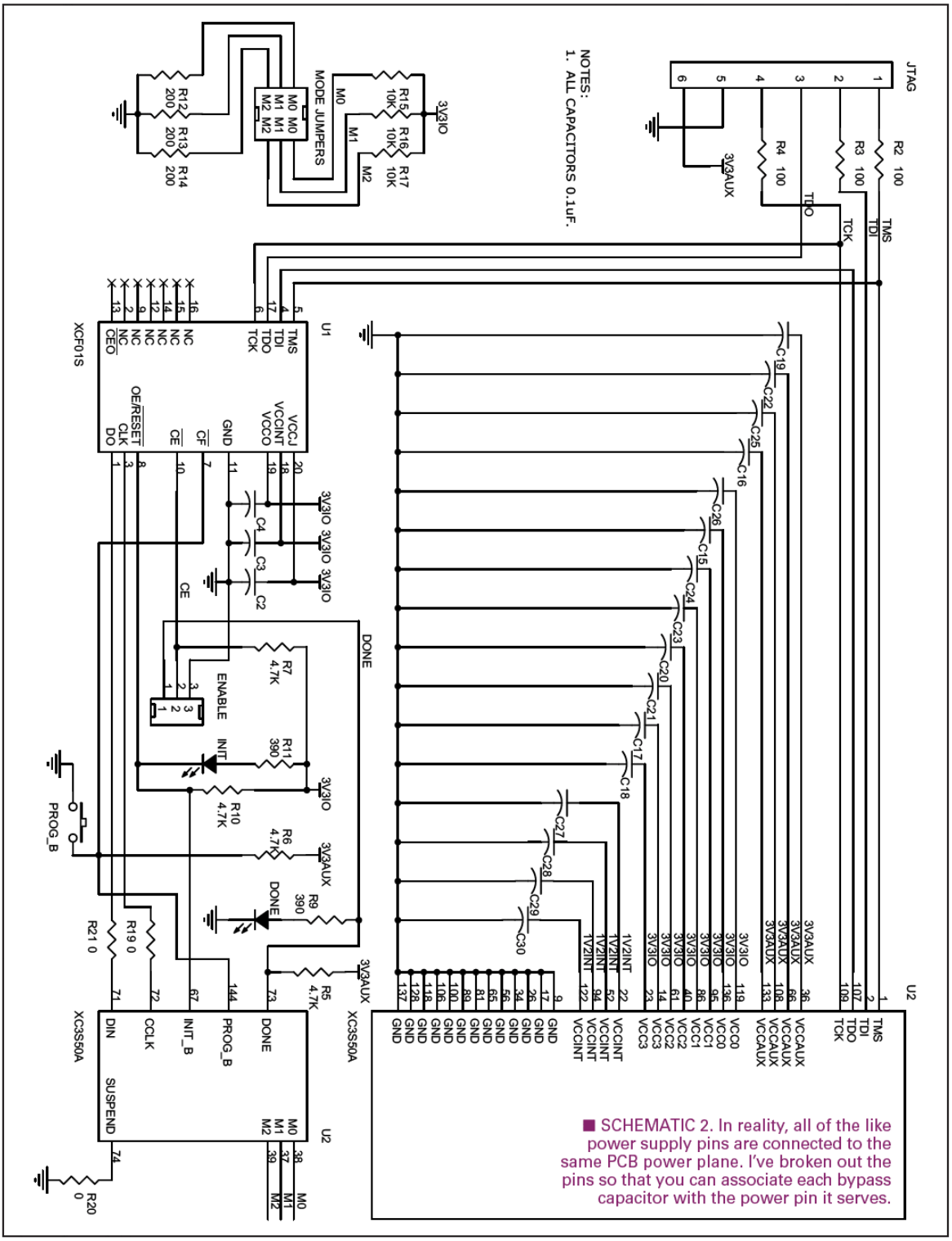
I introduced you to the Xilinx platform cable USB programming device when we were adding CPLD devices to your Design Cycle. I also used this programming device for our foray into FPGAs. We will use the platform cable USB again to drop code into our 50A design. To gain access to the services of the platform cable USB, all

■ PHOTO 2. Using these LDO voltage regulators only required a couple of extra solder joints each. We have the space, so I designed in the large tantalums. In a space-constrained application, we can ditch the big caps and go with the smaller ceramics.

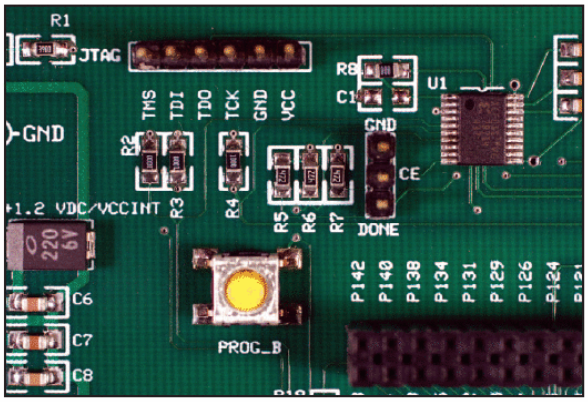


■ PHOTO 3. These 0603 .1 µF capacitors are tiny. However, I managed to tie them all down using a standard soldering iron.





■ SCHEMATIC 2. In reality, all of the like power supply pins are connected to the same PCB power plane. I've broken out the pins so that you can associate each bypass capacitor with the power pin it serves.



■ PHOTO 4. This shot is an overhead view of the XC3S50A JTAG interface hardware and the 1 Mbit Xilinx Platform Flash PROM (U1) that is used to boot the 50A. The PROM is enabled and selected by the position of the CE (Chip Enable) jumper. The PROG_B pushbutton is actually the FPGA reset button that prompts the PROM to reload the configuration.

we have to do is lay in a JTAG interface on our garage-built development board.

The entire JTAG hardware interface is part of Schematic 2. You can see the actual JTAG hardware in Photo 4. The only new trick we employ with this JTAG interface that we did not pull out of our CPLD hat is the addition of a Xilinx Platform Flash PROM, which is included as part of the now two-device (XC3S50A and XCF01S Platform Flash) JTAG programming chain. The XCF01S is woven into the JTAG chain by redirecting the 50A's TDO (JTAG Serial Data Out) line to the XCF01S's TDI (JTAG Serial Data In) pin. The XCF01S's TDO pin is then routed to the JTAG programming connector's TDO pin, which completes the JTAG programming chain.

The PROG_B pushbutton performs the same task as a microcontroller's reset pushbutton. Depressing the PROG_B pushbutton will force the 50A to drive its INIT_B pin logically low and enter master reset mode. The alternate way to enter master reset mode and drive the INIT_B pin logically low is to repower the chip. During the time that the INIT_B pin is low, the 50A is performing what is termed FPGA housecleaning. "Housecleaning" here is the act of clearing internal configuration memory. The INIT LED illuminates during this process. Once the 50A is loaded, the INIT_B pin can be configured to drive logically low in the event of a CRC error. The DONE pin is driven logically high when all of the configuration data has been successfully loaded. A successful configuration data load is signaled by the illumination of the DONE LED and inactive INIT LED.

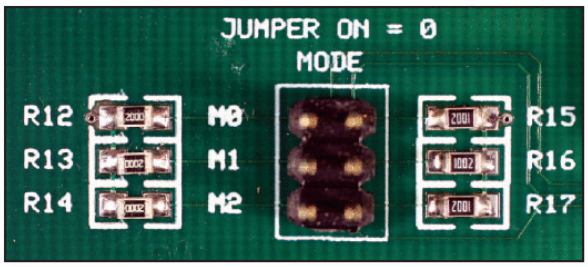
If we wish to program the 50A from the JTAG interface, we must place a jumper across the M1 mode select pins. We must also instruct ISE WebPACK to assign the startup clock to the JTAG interface. Placing jumpers on M0, M1, and M2 puts the chip into Master Serial mode, which forces it to generate a clock signal on its CCLK pin. In Master Serial mode, the CCLK clock signal drives the XCF01S PROM to read its configuration data. The startup clock value in ISE WebPACK must be set to CCLK in Master Serial mode. The mode jumpers can configure the 50A for slave modes, as well. However, our 50A design does not include any slave mode hardware. Our mode select hardware can be seen in Photo 5.

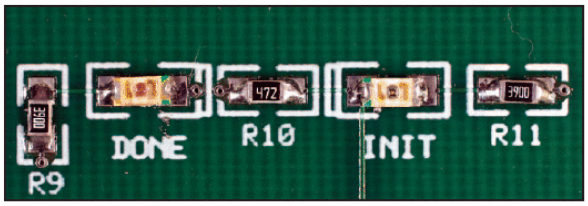
The XCF01S PROM's DO (Data Out) pin can be permanently enabled by grounding the XCF01S's CE (Chip Enable) pin. This is useful if we have a need to access the contents of the XCF01S after the configuration data has been downloaded. We can also choose to jumper the XCF01S PROM's CE pin to only be active while the 50A DONE pin is being driven logically low. Doing this only allows the XCF01S to regurgitate the extent of the configuration data. No post-configuration XCF01S access is permitted as the DONE pin is driven logically high at the end of the configuration data download process.

If you're wondering how we get that configuration data into the XCF01S in the first place, no worries. We tell ISE WebPACK to generate a pair of configuration files that can be loaded into the XCF01S and the XC3S50A. If our hardware is connected correctly to the JTAG chain, the ISE WebPACK iMPACT programming application and the program cable USB programmer are able to see both of JTAG devices. With that, we are able to tell iMPACT which device and which configuration file we want to load via the JTAG connection.

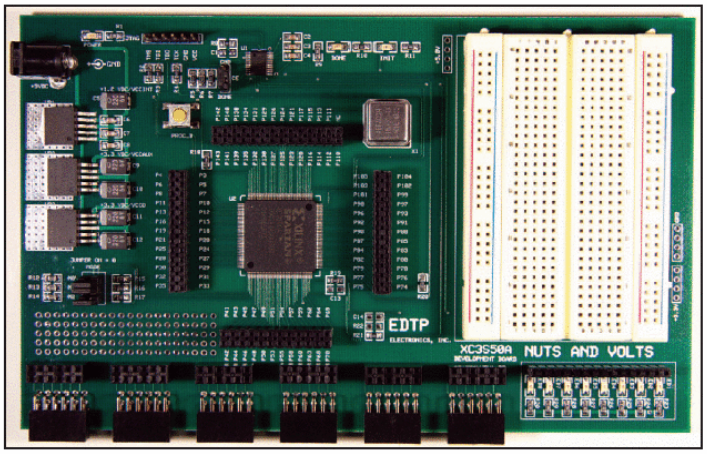
The actual XCF01S Platform Flash IC and supporting hardware are represented in Photo 4. Schematic 2 holds the logical XCF01S presentation. The DONE and INIT status hardware is shown in Photo 6.

■ PHOTO 5. Unless you decide to add some slave memory devices, we'll only jumper M1 for JTAG mode operation and all of the mode jumpers for master serial mode operation.

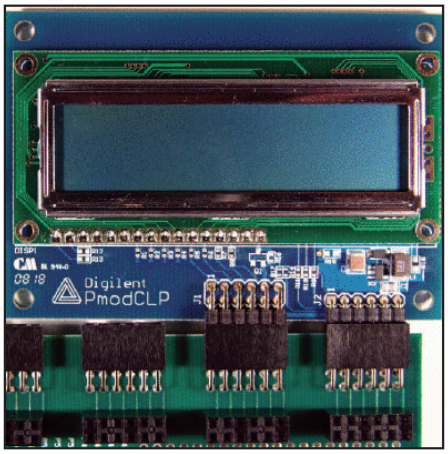




■ PHOTO 6. Resistor R10 is acting as an auxiliary external pullup to assist the INIT_B pin's weak internal pullup. The INIT LED will illuminate dimly upon successful configuration download unless you instruct ISE WebPACK to pull up the INIT_B pin after the configuration download.



■ PHOTO 7. All of the lessons learned from the XC2C64A CPLD development board project have been incorporated into the development board you see here.



■ PHOTO 8. I designed the XC3S50A development board's I/O ports to accept the six-pin footprint of the Digilent series of prefabricated I/O modules. Most of the Digilent I/O modules sport single-row interfaces. The LCD module in this shot has both single-row and double-row six-pin I/O interfaces. You can also easily see the relationship between the right-angle and straight-up 2 x 6 connectors in this view.

COMPLETING THE XC3S50A HARDWARE DESIGN

I couldn't decide which clock frequency would work best. So, instead of designing in a permanent clock oscillator, I decided to include a four-pin socket to accommodate 3.3 volt, half-sized clock oscillator modules.

The Jameco (**www.jameco.com**) solderless breadboard module worked out very well in the XC2C64A CPLD design, so I have included it in our XC3S50A design. I also pulled the CPLD LED bank into our FPGA design. Another point that proved itself in the CPLD design was the use of female interconnect points. As you can see in Photo 7, I have used female I/O connectors exclusively in this design.

Rather than try to cram every conceivable peripheral onto this development board, I added six 2 x 6 I/O peripheral portals. Each right-angle 2 x 6 female interface is directly wired to a companion 2 x 6 straight-up female connector. The beauty of these I/O portals is that they are compatible with a series of prefabricated I/O modules that are available from Digilent. The Digilent I/O module series includes seven-segment LED displays, H-bridges, pushbutton arrays, slide switch arrays, RS-232 interfaces, and LCD modules. In many cases, pictures speak louder than words. So, let's work on putting the Digilent LCD module you see in Photo 8 to work.

FPGA TO LCD

The PmodCLP LCD module is unique in that it operates at 3.3 volts. An on-board boost voltage converter hops up the incoming 3.3 volts to 5.0 volts needed by the LCD electronics. Thus, it is very easy to interface the PmodCLP module's power, data bus, and control signals into our 3.3 volt XC3S50A system.

The PmodCLP J1 connector is not divided into odd and even rows as one would expect. I discovered this when the FPGA power supply shut down when I plugged the PmodCLP into the sockets I had wired into the FPGA. Instead, count from J1 pin 1 along the same row to J1 pin 6. J1 pin 7 is positioned relative to J1 pin 1 and you count down the J1 pin 7 row to J1 pin 12. I've included a schematic of the PmodCLP in the FPGA download package, which you can get on the *Nuts & Volts* website (**www.nutsvolts.com**).

All of the PmodCLP's data I/O lines are terminated on its J1 pins. The PmodCLP's J2 pins transfer the PmodCLP's E (Enable), RS (Register Select), and R/W (Read/Write) LCD control signals. Power for the PmodCLP can be applied to power pins within the J1 or J2 connectors.

I can best show you how the PmodCLP hardware connects and operates by showing you the Verilog code. So, let's start from the top of the Verilog LCD driver code and work our way down:

```
module lcd_drvr(
     input clk_10mhz,
     input reset,
     output reg lcd_e,
     output reg lcd_rs,
     output reg [7:0] lcd_data,
     output reg [7:0] led_out
  );
```

Hopefully, the module definition code snippet looks familiar. Our input clock frequency is 10.0 MHz. The input clock is tied by PCB trace to pin P124 of our XC3S50A. The active-low reset input connects to pin P33 of the FPGA. We'll use the reset input as a firmware reset to make sure that all of our LCD driver variables are initialized to our predetermined states. With the exception of the led_out output register, the rest of the registered outputs are associated with the

LCD control and data lines. I threw in the LED output to aid in debugging and to keep the LED bank busy when the LCD operates. I used the LEDs to debug by switching certain LEDs on when I arrived at a desired point in the execution of the LCD driver code. For instance, I turned on LED1 when I entered the display_set code area.

The PmodCLP LCD module's chipset command set is much like that of the industry standard HD44780 LCD chipset. Thus, we can use existing HD44780 microcontroller code to model our Verilog PmodCLP driver firmware. Here are the FPGA register layouts we will need to display characters on our PmodCLP:

```
reg   [3:0]   lcd_state;   //current LCD driver state
reg   [19:0]  lcd_clk;     //LCD function timer
reg   [8:0]   char_ptr;    //points to next character
                           //to display on LCD
reg    [8:0]  char2display;//the character to
                           //display on the LCD
reg   [22:0]  clk_divider; //used to slow down LED
                           //blink rate
```

Now that we have places to store states, clock counts and ASCII characters, let's parameterize the PmodCLP commands we will be using in our Verilog LCD driver code:

```
parameter cmd_function_set = 8'h3C, //8-bit interface,
                                    //2-line display
          cmd_display_set  = 8'h0C, //LCD on, no
                                    //blink, no cursor
          cmd_display_clr  = 8'h01, //clear the LCD
          cmd_entry_mode   = 8'h06, //shift to right
          cmd_display_home = 8'h02, //move to home
                                    //position
          cmd_display_line2 = 8'hC0; //move to line 2
```

Since we took the time to hack out some space for a register called lcd_state, that's a good indication that we're probably going to use a state machine approach in our LCD driver code. Here are the states we will be traversing:

```
parameter   power_up      = 4'h0,
            function_set  = 4'h1,
            display_set   = 4'h2,
            display_clr   = 4'h3,
            display_home  = 4'h4,
            display_msg   = 4'h5,
            msg_table     = 4'h6,
            display_line2 = 4'h7,
            idle          = 4'h8;
```

Implementing a state machine in our Verilog-based LCD driver makes the code easy to understand and follow. Most of the states operate in a similar manner to the function_set state. So, to gain an understanding of how the state machine code works, we'll take a detailed look at the function_set state source code.

Each tick of our clk_10mhz clock source is equivalent to 0.1 µs. Thus, it takes 10 clocks to span a time of 1.0 µs. Since the lcd_clk value drives the internal LCD task execution timing within a state, we always want the lcd_clk register to have a value of zero when a state is entered. That's especially true when we call the first of the initialization states, which happens to be the function_set state. That's where the reset code comes into play. Here's what the reset routine looks like:

```
always @(posedge clk_10mhz or negedge reset)
      begin
           if(reset == 0)
        begin
           lcd_e     <= 0;
           lcd_rs    <= 0;
           lcd_clk   <= 0;
           lcd_state <= function_set;
           char_ptr  <= 1;
        end
           else
        begin
           case(lcd_state)
```

I instructed the ISE WebPACK application to apply a pullup to the reset I/O pin. When the reset pin is taken logically low, the initialization of the LCD control lines takes place along with the clearing of the LCD internal task clock. Within the reset routine, the next state to be entered following a reset operation is set for function_set and the character-to-display pointer is set to the point to the first ASCII character in the message table.

If the reset input is not logically low, the LCD state machine code is allowed to execute. Our state machine is actually a Verilog case structure. The states we parameterized earlier are used as case statement arguments. The reset code assigned the function_set parameter as the next case argument is done by loading the lcd_state register with the function_set parameter, which equates to binary 0001. Here's the case code that makes up the function_set state:

```
function_set:
begin
    if(lcd_clk == 400) //40 uS
    begin
        lcd_clk <= 0;
        lcd_state <= display_set;
    end
    else if(lcd_clk == 20)
    begin
        lcd_e <= 0;
        lcd_state <= function_set;
        lcd_clk <= lcd_clk + 1;
    end
    else if(lcd_clk == 10)
    begin
        lcd_e <= 1;
        lcd_state <= function_set;
        lcd_clk <= lcd_clk + 1;
    end
    else
    begin
        lcd_rs <= 0;
        lcd_data <= cmd_function_set;
        lcd_state <= function_set;
        lcd_clk <= lcd_clk + 1;
    end
end
```

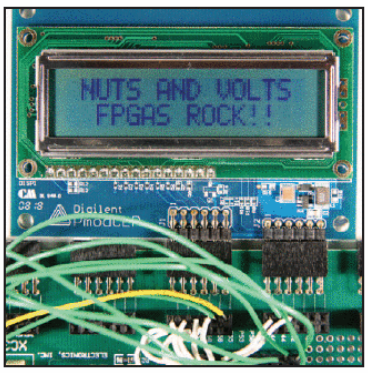
When the function_set case code is entered, the lcd_clk register value is equal to zero. Thus, the execution begins in the else clause, which resides at the end of the function_set code. The PmodCLP's RS control line is driven logically low for a command operation and the function_set command

bits are written to the PmodCLP's data bus. We have to raise the PmodCLP's E control pin logically high for a minimum of 220 ns and then bring it logically low for another 280 ns to allow the PmodCLP's LCD electronics to process the function_set command. So, we start the lcd_clk ticks within the else clause by incrementing the lcd_clk register.

We give the PmodCLP's LCD controller plenty of time to digest the signals on the RS pin and databus as the PmodCLP's E control line is raised to a logically high level 1 µS later when the lcd_clk value has been incremented to 10 ticks. The E control line will remain at a logically high level for 10 more ticks. When the lcd_clk value is equal to 20 ticks, the E control line will be driven logically low. We must wait a minimum of 37 µs before issuing the next command. The lcd_state register is loaded with the next desired state and the function_set state is exited when the lcd_clk expends another 38 µs (lcd_clk == 400). In addition to setting up the next state to hop to, upon exiting the function_set state we also clear the lcd_clk tick count to zero. As you can see in the function_set source code, we worked our way through the case statement code from bottom to top performing tasks according to the ticks contained within the lcd_clk. Note also that we always made sure that the lcd_state register was loaded with the currently executing state as we incremented the lcd_clk register to its exit value. There's only one state that doesn't operate in the manner we've just examined. However, I don't think that you will have any problems grasping the concepts used in the msg_table code:

```
msg_table:
      begin
            if(char_ptr == 17)
    begin
       lcd_clk <= 0;
       lcd_state <= display_line2;
    end
            else if(char_ptr == 34)
    begin
       lcd_clk <= 0;
       lcd_state <= idle;
    end
            else
    begin
       case(char_ptr)
       //LINE 1
       1:char2display <= " ";
       2:char2display <= "N";
       3:char2display <= "U";
       4:char2display <= "T";
       5:char2display <= "S";
       6:char2display <= " ";
       7:char2display <= "A";
       8:char2display <= "N";
```

■ PHOTO 9. I still get excited when things like this go as planned. In the end when the firmware and hardware are proven to work, it just doesn't get any better than that.



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```
            9:char2display <= "D";
            10:char2display <= " ";
            11:char2display <= "V";
            12:char2display <= "O";
            13:char2display <= "L";
            14:char2display <= "T";
            15:char2display <= "S";
            16:char2display <= " ";
            //LINE 2
            18:char2display <= " ";
            19:char2display <= " ";
            20:char2display <= "F";
            21:char2display <= "P";
            22:char2display <= "G";
            23:char2display <= "A";
            24:char2display <= "S";
            25:char2display <= " ";
            26:char2display <= "R";
            27:char2display <= "O";
            28:char2display <= "C";
            29:char2display <= "K";
            30:char2display <= "!";
            31:char2display <= "!";
            32:char2display <= " ";
            33:char2display <= " ";
            endcase

            lcd_clk <= 0;
            lcd_state <= display_msg;
        end
    end
```

The msg_table state is invoked by the display_msg state. The display_msg state code pulls 16 characters from the msg_table case structure one character at a time. There is no character 17 since it is a command to move to the beginning of the second line of the LCD. Characters beginning with the case statement argument of decimal 18 are fetched and written to the second line of the PmodCLP. When all of the 32 characters have been fetched and displayed, the idle state is invoked. The fruit of our labor is shown in Photo 9.

YOU SHOULD DO THIS, TOO

If you like working with microcontrollers, you'll love working with FPGAs. To tie up any loose ends, I've supplied the full ISE WebPACK Verilog PmodCLP driver project in the XC3S50A development board download package. Providing the ISE WebPACK project allows you to see all of the FPGA I/O assignments and all of the ISE WebPACK project parameters I used to put characters on the PmodCLP and blink the LEDs. For those of you that wish to build up your own 50A circuitry, I've also included the development board in an ExpressPCB format file in the download package. Now you have everything you need to add FPGAs into you Design Cycle. **NV**

SOURCES

Xilinx — **www.xilinx.com**
PXC3S50A; XCF01S; ISE WebPACK; Platform Cable USB

CONTACT THE AUTHOR

■ *Fred Eady can be contacted via email at fred@edtp.com.*

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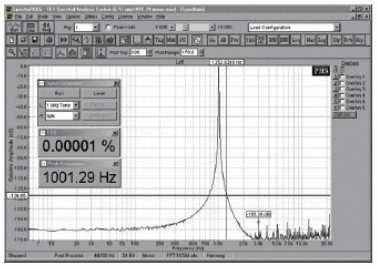

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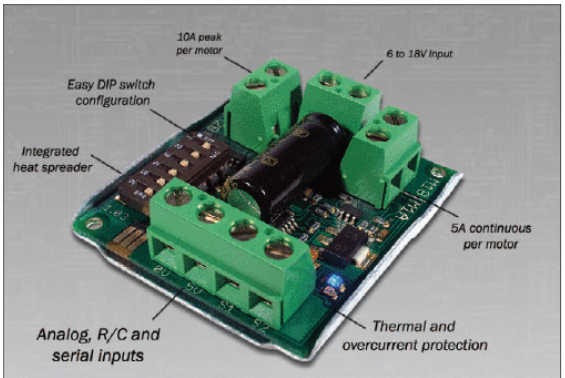

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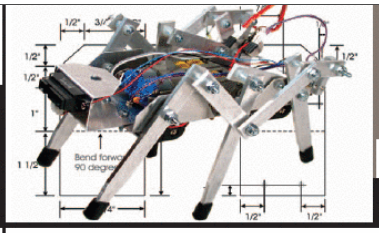


■ BY VERN GRANER

HABITAT FOR HOBBIES — PART 2

IN THE PERSONAL ROBOTICS COLUMN "Habitat for Hobbies — Part 1" (June '08 *Nuts & Volts*), I featured the workbenches of some of the *Nuts & Volts* readers. Not only did we get pictures of their environments, but many folks shared their stories and philosophies about how to create a productive and functional workspace. In this month's column, I'll complete the series by showing my own workspace (it's only fair, after all), sharing a bit of my design approach, and announcing the winners of the Workbench Design Challenge!

A PLACE FOR EVERYTHING AND EVERYTHING OUT OF PLACE?

As a kid growing up, my dad had a well-equipped workbench in the garage. He used it for maintaining our vehicles, fixing toys (i.e., reassembling things someone took apart), and reviving the occasional kitchen appliance. He had a typical mechanic's toolbox with wrenches, screwdrivers, socket sets, and the like. Many of his tools were decades old and proudly bore the grease stains of their use. When my dad was in high school, he decided he wanted a car so with the help of his friends he built one (from the ground up!) in his garage with those tools. The car ended up winning quite a few drag races and even ended up on the cover of HOW *Magazine* in 1957 (Figure 1). Maybe that's where I get the fearless approach I have to tackling big projects.

My understanding of tools and workbench design was inspired by my dad and how he kept his bench. However, I must admit that my dad's approach to workbench layout was much more organized than mine has turned out to be. I don't know if I'm just inherently less organized than "dear 'ol dad" or if it's more a matter of "form follows function." For example, the function of his workbench seemed to be focused on taking existing things and restoring them to functional states (or performing maintenance to keep them functional). There was usually a clear task to perform and specific tools required to do it. Whereas *my* workbench

■ FIGURE 1. The 1957 *HOW Magazine* cover featuring Wally Graner's home-built flathead V8. Also on the cover were (top) Don Johnson, (right) Al D'minco, (left) Marilyn Dobbins, and (bottom) Wally Graner.

■ FIGURE 2. Vern Graner's workbench — a converted closet approximately 6' x 10' showing how it looks during the course of a typical project.

■ FIGURE 3. Notice the air conditioner unit in the top right corner? Lights, computers, soldering irons, and other equipment give off quite a bit of heat!

■ FIGURE 4. Storage rack to the left of my workbench holds partially assembled projects, broken "junk" pieces, parts, and (in many cases) inspiration.

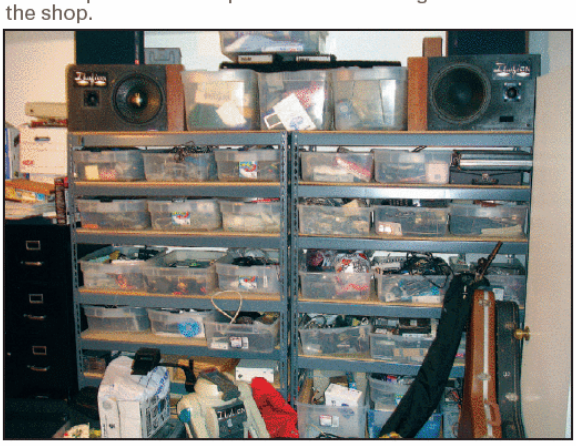
has to be able to support the creating or inventing of things that only exist in vague concepts or rough sketches. In many cases, I don't know exactly what I will need till I'm done with a build! Have a look at the Ponginator (*N&V* December '07), the RoboSpinArt machine (*N&V* January '08), the Ping Pong Printer (*N&V* February '08), or the Power Flowers (July '08) for good examples of what I'm talking about (see Resources for links to videos).

I KNOW IT'S HERE SOMEWHERE ...

When looking at the pictures that came in from all around the country for the first Habitat column, I started to wonder ... am I really that much less organized than other folks, or did some of you just clean up your workbenches before sending in the photos? The bottom line is that my workspace is typically a visual cacophony of parts, tools, documentation, media, wire, and well ... just have a look at the pictures of my bench in Figures 2 and 3 and you can see quite clearly.

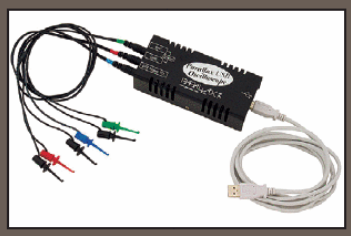
Somehow though, I can usually lay my hands on just about anything I need. I seem to have a "relational" memory in that I can remember approximately where something is "buried" and then home in on that area of my workspace to find it (Figure 4). I try to keep like-parts in the same place so if I can't find exactly what I set out to find, I can usually find something similar (Figure 5). Although I drool over the highly organized workspaces such as those submitted for Part 1, I imagine that if I were to create one, it would quickly become just as chaotic as my existing workspace is. I do try, though. For example, before I begin a project, I start by cleaning up my workbench and putting all the tools and parts away. However, when I'm actually creating stuff (Figure 6), I'm just too busy to put things back carefully where they belong. My wife thinks it's laziness ... I blame entropy. But

■ FIGURE 5. Main storage rack just outside the door to the 60 square-foot "shop" hold items too big to fit inside the shop.

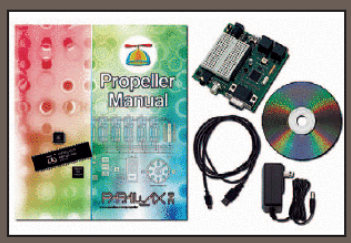


■ FIGURE 6. The workbench at project start-up sporting the parts that would eventually become an animatronic haunt controller.

■ *1st place prize*: A Parallax USB Oscilloscope.



■ *2nd place prize*: A Parallax Propeller Starter Kit.



■ *3rd place prize*: A Parallax BASIC Stamp 1 Starter Kit.

enough about my workbench, let's have a look at some workbenches created under some unusual and rather challenging conditions.

THE $100 WORKBENCH DESIGN CHALLENGE WINNER!

I had quite a few entries in response to the challenge and I have to say it was a lot tougher to determine a clear winner than I thought it would be! After much soul searching, internal arguments, sleepless nights (okay, maybe a coin toss or two), the prizes went to the following entrants:

3RD PLACE – NICHOLAS KUCKUCK OF ROSEBURG, OR

Though only 13 years old, Nicholas did a thorough job of researching parts and tools. He was one of the first entrants to choose "surprise" packages of bulk components from vendors to save money while stocking up on parts. His entry had a good balance of parts, test gear, components, and tools.

2ND PLACE – JESS LEWIS OF CHANDLER, AZ

Jess was the first entry I received and it helped set the tone for all the entries that followed. He include a nice cross-section of tools and parts coupled with a succinct summary of the reasons for his choices. He also included links to websites where you can download free software that would allow a PC to be used as an oscilloscope and a curve tracer (see Resources). The inclusion of "grab bag" bulk items from some vendors was an added plus.

And the winner of the Workbench Design Challenge:

1ST PLACE – ANDREW AYERS OF GLENDALE, AZ

In the end, I kept coming back to the entry from Andrew Ayers of Glendale, AZ. It's pretty amazing what he managed to get done with a measly $100! Andrew spent a good portion of his entry to describe the reasoning behind his choices and topped it off by doing extensive Internet research from many different vendors to find all the things he needed. His careful shopping left him with just enough money to buy a piece of bubble gum! Check out Andrew's award-winning entry in the sidebar.

Congratulations to Andrew and to all the contest entrants. Contest winners will be receiving their prizes in the mail directly from Parallax.

I'd like to take a moment to personally thank Ken Gracey of Parallax fame for providing the prizes for this fun contest. I also want to announce that for those of you who took the time to enter (but did not win) your work was not in vain. We will be sending a small (but quite useful!) prize to each and every person who sent in an entry!

Thanks again to all those who participated. I will be posting all the entries to the *Nuts & Volts* forum so people can compare the entries and discuss workbench design. As always, if you have comments, feedback, or suggestions for articles, please feel free to email me at vern@txis.com. **NV**

RESOURCES

■ Parallax, Inc.
www.parallax.com

■ Jess Lewis Links:
Sound Card Oscilloscope Hardware and Software
http://xoscope.sourceforge.net

Curve Tracer
www.techlib.com/electronics/curvetrace.html

■ Workbench Design Challenge Discussion
http://forum.servomagazine.com/viewtopic.php?t=8204

■ Ponginator
www.youtube.com/watch?v=iPSoFYHywJw

■ RoboSpinArt
www.youtube.com/watch?v=bEKPDoNCyZk

■ Ping Pong Printer
www.youtube.com/watch?v=8Ep5OC3E02I

■ Power Flowers
www.youtube.com/watch?v=Ydkk4-6FsWk

■ The Robot Group
www.TheRobotGroup.org

■ Andrew Ayers Website
www.phoenixgarage.org

ANDREW'S $100 ELECTRONIC WORKBENCH CHALLENGE ENTRY

Early in the process of selecting items, I decided to base my purchasing decisions toward the goal of stocking an entry-level robotics and industrial automation workbench. Over the course of recent years, hobby-bench level electronics have been focusing on the usage and programming of microcontrollers. These devices have allowed for the increasing simplification in designs that would have taken many more discrete components in the past to implement. Instead, the complexity of hardware is reduced by implementing more functionality in software.

I felt that stocking a general-purpose workbench went against this reality, and so the decision was made to focus my selections around the standard, widely-used PIC16F84A microcontroller. Narrowing the focus even further to robotics applications adds an element of excitement — the student's projects can now move, and the results of their development can be seen in a tangible way.

TOOLS

I decided to focus first on the tools. I wanted them to be quality tools that the student could use potentially for a lifetime, provided they are well taken care of. At the same time, I had to be mindful of cost. This necessitated the goal of obtaining as much functionality as I could for the price from each tool in the set I assembled.

A good multimeter was a must. While certainly not a Fluke, I personally own a couple of the low-cost multimeters I selected for this workbench, and I have found them to be very capable and reliable tools for a fraction of the cost. The good selection of ranges, transistor/diode testing capabilities, and small size make this multimeter an excellent introductory choice for the workbench. The soldering iron seemed like a good selection because it is of a low enough wattage to handle some of the more fragile components without overheating, while still having enough power to solder larger components with ease. The grip seemed like it would be comfortable for longer periods of use, and the grounded plug should help with ESD issues.

The soldering iron stand combines both a third-hand with magnifier with a soldering stand complete with sponge, which means less room on the workbench taken up by individual tools (which is always a plus when prototyping and assembling circuits). The magnifier allows for easy visual inspection and correction of solder joints as needed. A small but adequate amount of 60/40 solder rounds out the soldering station supplies.

The 25 piece Velleman tool set is similar to a tool set I own. For the price, it cannot be beat on the necessary selection of tools you get: miniature wire cutters, long nose pliers, tweezers, multi-bit screwdriver, and a selection of precision screwdrivers are all included. All are very handy to have on the workbench. The carrying case is a bonus.

A desoldering tool and alligator clips complete the tool package for entry level usage. While we can strive to never make a soldering mistake, inevitably it creeps in, regardless of skill level, and the desoldering tool can save the day. Alligator clips provide quick hookup of parts that just need temporary connections during prototyping.

PROTOTYPING

All electronic workbenches need prototyping tools. The solderless breadboard chosen affords the student plenty of room to develop and test a variety of microcontroller interfacing circuits. Hookup wire can be used for soldered connections or as wire jumpers on the solderless breadboard, at a price point much lower than formed wire jumpers. A battery holder and connectors with four AA batteries provides a simple and portable DC power source for development. Finally, the prototyping PCB — with parts — can be assembled as a carrier board for the microcontroller, which can then be easily interfaced to circuitry developed on the solderless breadboard.

COMPONENTS

As mentioned previously, the standard, easy-to-use PIC16F84A was selected as the microcontroller for this workbench. A 20 MHz part was chosen to allow for future upgrades in speed, if so desired. The prototyping PCB discussed above was designed to use a 4 MHz oscillator crystal/resonator. The PIC selected can run at this lower speed, being rated for DC-20 MHz operation. To allow the user to program the PIC, a programmer is necessary. The following design was selected due to the simplicity of its construction, and the need for only standard and simple parts. Power for programming is derived from the host PC's serial port. Parts for the programmer are included in the list, while leaving enough parts for the student to prototype and construct other circuitry on the solderless breadboard, or elsewhere. The PIC16F84A is plugged into a socket on the programmer. The assembled hex file is uploaded to it, then the PIC is moved to the carrier board and interfaced to controlled circuitry as desired. The development software for creating the hex files can easily be found as open source software for most platforms, and is thus free for use by the student.

Various other passive and active components are provided to allow the student the capability to construct a variety of control and automation circuits. LED flashers and sequencers, relay and H-bridge motor control of a small DC motor, control of RC servos, and input from buttons and leaf switches are all capable of being constructed using the components provided, allowing the student to develop a wide set of skills and knowledge of robotics and industrial automation.

Projects utilizing these parts can be easily found on the Internet by the student. There is a plethora of designs and code available for the PIC16F84A; it is easily one of the most utilized microcontrollers in existence, mainly due to its simplicity and low cost.

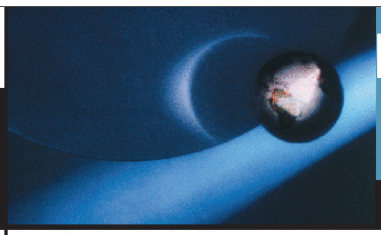
CATEGORY: TOOLS				
Qty	Item	Vendor	Part #	Price/ea
1	Multimeter	jaycar.com	QM1500	$4
1	Soldering Iron	circuitspecialists.com	200PHG-25WATT	$6.95
1	Soldering Stand	goldmine-elec-products.com	G12810	$4.98
1	Solder	allelectronics.com	TS-110	$1.25
1	Toolset	designnotes.com	VTTS	$9.85
1	Desoldering Pump	electronics123.com	VTD1	$2.91
1	Alligator Leads	circuitspecialists.com	M000F0003	$2.49
			TOTAL	$32.43

CATEGORY: PROTOTYPING				
Qty	Item	Vendor	Part #	Price/ea
1	Breadboard	pololu.com	352	$4.95
1	Hookup Wire	jaycar.com	WH3025	$2.25
1	Battery Holder 4AA	electronics123.com	H341B	$0.53
1	Battery Clip 9V	electronics123.com	SNAP9V	$0.21
1	Batteries 4AA	electronics123.com	BB099	$0.89
1	Prototyping PCB	imagesco.com	PCB-27WP	$14.95
			TOTAL	$23.78

CONCLUSION

I was unable to include everything I wanted to in this workbench (in particular, I wanted to add a simple oscilloscope or at least a logic probe, but neither were in the cards). By careful selection and research, I believe I have managed to include the necessities needed for the introductory student to explore a large swath of territory within the fields of robotics and industrial automation.

This contest proved quite an eye-opener for me. I had thought it was going to be simple; a virtual walk in the park. Instead, I found myself neck deep quite quickly, making decisions on parts and vendors based on costs, quantities available, and quality. I ended up with a new respect for individuals who have to do this on a regular basis — for their job, their students, or otherwise. Total cost for the entry $99.36 with $0.64 left over for some bubblegum (well, maybe not at today's prices!).



NEAR SPACE

APPROACHING THE FINAL FRONTIER

■ BY L. PAUL VERHAGE

NEAR SPACECRAFT RECOVERY SYSTEMS: PART 1

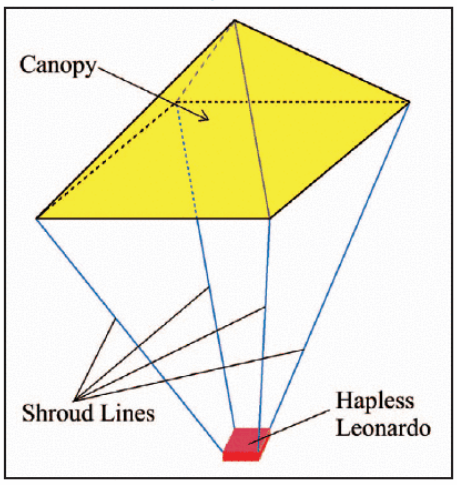
IT'S AWESOME TO RECEIVE DATA FROM YOUR near spacecraft at an altitude of 85,000 feet. Moreover, chances are good that if the sky is clear, you'll even see its balloon as a tiny white dot in the sky. At this altitude, the balloon is 20 feet across and expanding as it rises. Shortly though, that white dot in the sky disappears. Now it's up to the recovery system to bring your near spacecraft safely home.

HISTORY OF THE PARACHUTE

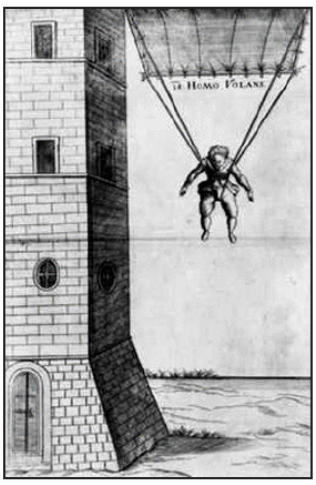
The original Renaissance man — Leonardo da Vinci (1452-1519) — drew a picture of one of the first parachutes in the early 1480s. Shown in Figure 1, Da Vinci's parachute isn't today's sport parachute; it's an inverted rigid pyramid and meant to save the lives of people trapped in burning buildings. There's no record that Da Vinci ever built (like many of his inventions) a working model of his parachute.

When Faust Vrancic (a.k.a., Fausto Veranzio) made the first parachute jump in 1617, it was still believed parachutes had to be rigid. In nearly 150 years of thought, no one had conceived that a soft fabric parachute could open on its own and remain opened. That's why Vrancic's parachute was a square of fabric sewn to an open framework of wooden boards as you can see in Figure 2.

It wasn't until the late 1790s that Frenchman Jean-Pierre Blanchard developed a parachute without the wooden frame. His foldable parachute was sewn from sheets of silk — a lightweight and strong material. As early as 1793, the parachute was used (by Blanchard) as a rescue device for ruptured balloons. That makes the near space recovery parachute a part of a 215 year history of parachuting.



■ FIGURE 1. An early parachute design by da Vinci. It should work, but it wouldn't be very safe or stable.

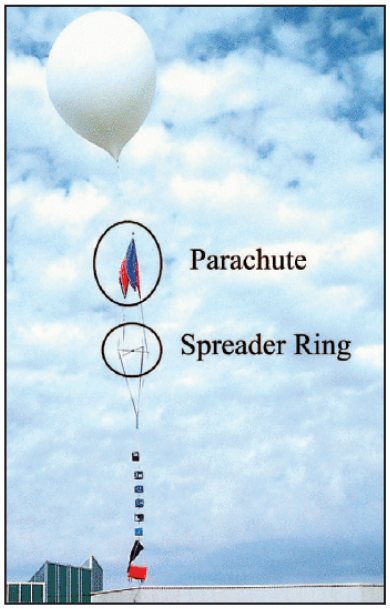


PARACHUTES FOR NEAR SPACE RECOVERY

The first rubber balloons to carry balloon sondes in the early 20th century relied on parachutes or multiple balloons to safely recover the payload and its data (Figure 4). Initially though, the multiple balloon method was the preferred method for retrieving the expensive payload.

■ FIGURE 2. Vrancic's large parachute design — the Homo Volans or Flying Man. Vrancic — like da Vinci — believed that a parachute could not hold itself open on its own. *Image from About.com:Inventors.*

■ FIGURE 3. The recovery parachute for this near spacecraft is visible between the balloon and its capsules. Below the parachute is its spreader ring.



In the multiple balloon recovery system, two or more balloons lift the meteorological payload to altitude. Together, all the balloons can lift the payload, but not when one or more have burst. The remaining balloon(s) "offsets" some of the weight of the payload as it drops earthward at a constant, but slow speed. Upon touchdown, the balloon(s) remains floating, signaling the location of the payload to the chase crew. With the advent of the radiosonde – which telemeters data to ground stations – instrument, recovery became less important and the parachute became a device to protect private property from the descending payload.

COMMERCIAL PARACHUTES

You can always purchase a parachute for your near spacecraft. Amateur rocket parachutes sold by companies like Rocketman (**www.therocketman.com**) are perfect for recovering a near spacecraft. In fact, I've used a slightly modified six foot Rocketman parachute to recover several of my near space payloads.

MAKING YOUR OWN

Where is the challenge and satisfaction of using a commercially manufactured parachute? Over the years, I've made half a dozen parachutes (like those in Figures 3 and 5) for my near space program, so let me explain how I did it and saved money. Afterwards, there'll be a little parachute science and engineering. First, never use a parachute that you've designed to recover living objects, except for insects and microbes. While your parachute may work perfectly well to recover payloads from near space, it's unethical to use a parachute that cannot be adequately tested for the recovery of living beings that are significantly aware of pain and suffering.

The parachute described here is a hemispherical. It's a popular parachute design but now obsolete for the recovery of personnel. With a coefficient of drag between 0.62 and 0.77, it's in the mid range of parachute effectiveness. I use this type of parachute because it's easy to design and make.

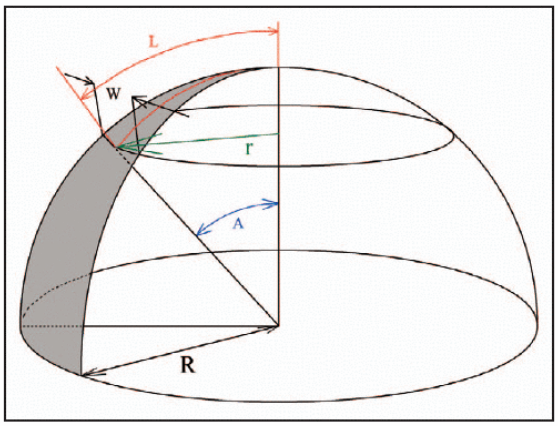
■ FIGURE 4. A 1944 radiosonde launch. Notice the recovery parachute blowing in the wind. *Image from the National Oceanic and Atmospheric Administration.*

THE GORE PATTERN

The hemispherical parachute in this article has a radius called R and consists of eight gores. Knowing R, we can use a spreadsheet to calculate the width of the gores as we run down its length. To do this, we'll need a dose of geometry. We'll start at the top of our hemisphere drawing and draw a line at an arbitrary angle (labeled as A in Figure 6). That angle intersects the parachute at a point that is at a length called L. The end of L intersects the hemisphere of the parachute to form a ring (with the radius called r in Figure 6) drawn around the parachute. Now we'll divide the circumference of the ring around the parachute by eight to calculate the width of the gore at length L and call that width W.

To help us see the relationship between angle A and the width of a gore, let's look at a two-dimensional thin slice of the parachute. We can see this becomes a problem of calculating the length r as angle A goes from 0 to 90 degrees. R (radius of the parachute) is the only constant length in this

■ FIGURE 5. While overkill for the typical near spacecraft, this 19 foot diameter parachute is identical in overall design to the six foot diameter parachute I've used.



■ FIGURE 6. This illustration shows how an arbitrary angle down a parachute relates to the radius of the circle and to the width of the gores, that form the final parachute.

problem. It's easier still to see if we look at just the triangle involved and rotate it.

We can see that as angle A increases, the radius r approaches the radius of the parachute (R). In trigonometry, sine = opposite/hypotenuse, or in our case, sin(A) equals r (radius of circle) divided by R (radius of parachute). Rearranging the terms, we get the equation, r = R*sin(A). After finding r, we calculate the circumference of the circle it creates by multiplying it by 2π.

The width of each gore is equal to the circumference of the circle divided by eight (the parachute has eight gores). The final width will be two inches wider for the one inch seam on every edge of the gores. However, since gores are symmetrical with respect to their central axis, we'll actually divide the calculated width of the gores by two and add one inch for the seam. The final table of gore widths and lengths makes it easier to draw the gore. So, putting all these elements together, we calculate the half-width of a gore as,

$$W/2 = 1 + [\pi * R * \sin(A)] / 8$$

The length along the gore that angle A generates is calculated by multiplying angle A by the ratio of 1/4 of the parachute's base circumference and dividing by 90 degrees. In other words,

$$L = A * \pi * R * (1/180)$$

As a parachute descends, pressure builds up inside its canopy until it forces the parachute to tip and vent the air. As a result, the parachute rocks (sometimes violently) during its descent. This was a serious problem for early parachute testers like Andre Jacques Garnerin who became so sick after parachute jumps that he often vomited after landing. To correct this defect, Joseph Lelandes introduced the vent hole to parachutes in 1804. I included a 15% vent hole in my parachute's design. A vent this size equates to a parachute with gores missing the first 10 degrees of their length.

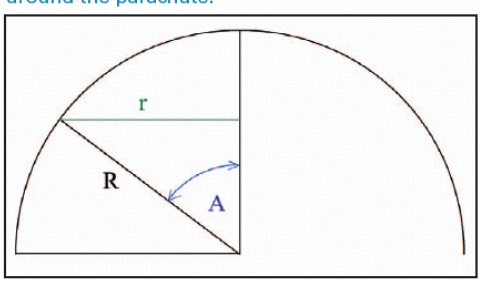
The equations created in this article have been loaded into an Excel chart that you can download from the *Nuts & Volts* website (**www.nutsvolts.com**). To use it, you only need to enter the diameter of the parachute in the cyan colored box. The spreadsheet calculates the half width of the gores at every five degrees and adds a one inch seam to the sides and two inch seams to the top and bottom of the gore. I didn't write the spreadsheet for finer than five degree increments because that would generate an unwieldy number of measurements for the gore pattern (killin' you with details). The chart on the second page of the spreadsheet diagrams in Figure 9 the resulting gore pattern. It's useful if you drag the top edge of the chart until it has the same scale as the side of the chart.

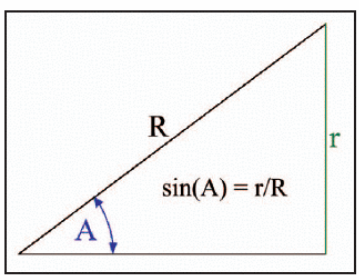
THE MECHANICS OF SEWING THE PARACHUTE

Parachutes are typically made from low porosity fabrics. If a porous fabric is used, then its diameter must be greater to make up for its lower braking ability. On the other hand, a porous parachute doesn't require a vent hole because pressure can't build up high enough to cause oscillations. Fabrics that work well for parachute canopies are the fabric from retired hot air balloons and rip stop nylon from your local fabric and sewing store. Hot air balloon material is less expensive than rip stop, but it's not available everywhere and it comes with a funny smell (from the propane used to heat the air inside). It takes several washings to remove the smell.

It's best to create a pattern for a gore and use it to lay out the pattern on the fabric (as in Figure 9A). Thin cardboard or poster board from craft stores and big box retailers works well for the pattern material. A parachute large enough to recover a near spacecraft requires two or three sheets of

■ FIGURE 7. A section taken from the parachute shows how the angle A relates to the radius of the circle (r) around the parachute.





■ FIGURE 8. Focusing on just the triangle involved.

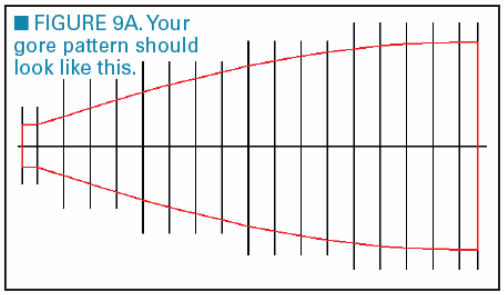
cardboard for its gore pattern; tape several sheets together before laying out the pattern. Draw a line down the middle of the poster board and then perpendicular lines at every five degree lengths (this is the length measurement in the spreadsheet). From the center line, mark the half width of the gore at every perpendicular in both directions since the gore pattern is symmetrical. Draw a smooth line connecting the half-width marks and you have the shape of the gore. Now cut it out.

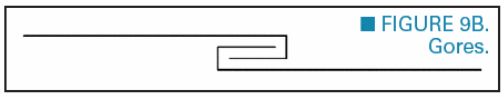
Lay out the parachute fabric and smooth out its wrinkles before drawing the pattern on it. If the wrinkles are very bad, you may want to iron the fabric first. Since it's nylon, be careful that the iron temperature isn't set too high or that the iron doesn't sit on the fabric too long. Line up the gore pattern with the heavier "rip-stop" threads woven into the fabric. When the long axis of all of the parachute's gores do not line up the same way with the rip-stop threads in the fabric, the parachute's shape can warp during a descent. It's easier to see the pattern in the fabric if a contrasting colored pencil is used to draw the outline of the gore pattern.

Rather than cutting out the gores with a pair of scissors, use a hot cutter. Hot cutters are essentially soldering guns with a rounded tip. The tip melts its way through the nylon fabric which prevents it from fraying. You'll find hot cutters in some soldering gun kits and at kite stores. Lay the fabric on a sheet of Masonite before you begin cutting it. The Masonite will protect the table you cut the fabric on.

After cutting out the gores, fold the top and bottom seams over by one inch and iron the seam in. Then interlock the sides of two gores together as illustrated in Figure 9B.

■ FIGURE 9A. Your gore pattern should look like this.

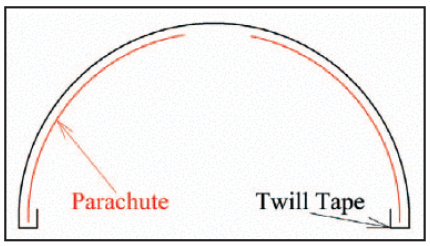




■ FIGURE 9B. Gores.

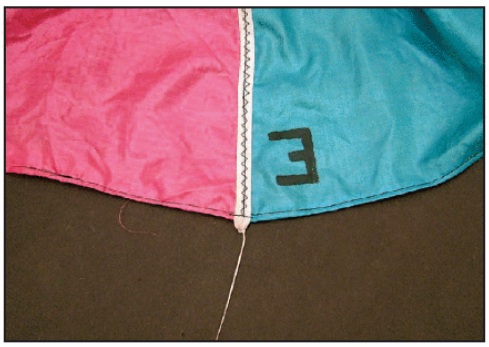
The seam between the gores is temporary because the seam needs a strip of 1/2 inch wide bias or — better still — twill tape for strength. Cut four pieces of twill tape to a length six inches greater than half the circumference of the parachute. Then mark each tape at its center and at five and six inches from both ends. Lay a twill tape on top of a gore seam and align the tape down the center of the seam. Shift the tape until the tape's six inch mark lines up with the bottom of the parachute canopy and hold it in place with a few hand stitches. Do the same with the other end of the tape on the opposite side of the canopy. Repeat this process of aligning the rest of the tapes on the parachute canopy. When done, the twill tapes lay on the top of the parachute and cross each other close to their center points and are centered over the parachute's vent hole.

Fold the ends of each twill tape at their five inch marks so the ends of



■ FIGURE 10. A cross section of the parachute illustrating the placement of seam reinforcing twill tape.

■ FIGURE 11. Shroud lines tie to the eight loops at the bottom of the parachute. Each loop forms as the reinforcing twill tapes wrap around the bottom of the parachute.



THE PARACHUTE GORE IS NOT RELATED TO AL GORE

Fabric is made by weaving together two yarns (yarn is twisted threads). The vertical (or lengthwise yarn) is called the warp and the horizontal (or side to side yarn) is called the weft. In the case of rip-stop nylon, the fabric consists of threads of twisted nylon fibers or monofilaments. The end product is a flat sheet of twisted and woven nylon monofilaments.

Since ripstop is a flat two-dimensional sheet that doesn't stretch, it can't bend into a three dimensional shape like a hemisphere without wrinkling. *Nuts & Volts* readers learned this when they cut out and folded their first paper cube in elementary school. In the case of the hemisphere, the shape is modeled by changing its continuous curved surface into a series of neighboring flat strips. The narrower and more numerous the strips, the more closely the modeled shape becomes a perfect hemisphere. However, the thinner the strips, the more time is spent cutting and sewing them into a parachute. Not only does it take more time and work, but it makes the final parachute heavier due to the additional seams and sewing. Each of the parachute's flat panels is called a gore. The old World War II parachutes you see in the movies are made with a greater number of gores since the parachutes are so much larger. In the parachute design in this month's column, an eight gore design was selected as the happy medium between the perfect hemisphere and a paper cube.

You can learn more about weaving yarn into fabric at Wikipedia. I found a good webpage on sewing kites (which is similar to sewing parachutes) online at Kite Sewing 101, **www.geocities.com/gengvall/sew/sew.html**.

IT'S A DRAG

Drag is a force that opposes the motion of an object. If it's stationary, then the force of drag equals zero, and the faster it moves, the greater the force of drag. In the case of a falling object, the force of gravity governs the speed at which it falls until it reaches a terminal velocity balanced by drag. The two forces — gravity pulling down and drag pulling up — equal each other at terminal velocity.

The force of drag acting on a body moving through a medium can be described with this formula:

$$F_d = \frac{1}{2} \rho v^2 C_d A$$

where
- ρ is the density of the medium the body is moving through
- v is the velocity (speed) of the body
- C_d is the body's coefficient of drag
- A is the frontal area of the body

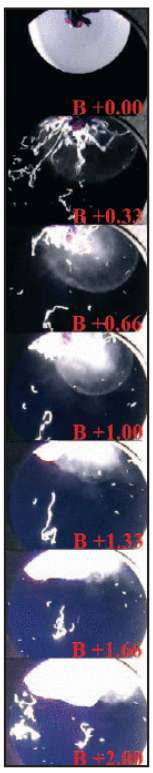
These factors are easy to understand except for one: C_d. The coefficient of drag is a dimensionless constant. Being dimensionless means it has no units like meters, seconds, or grams. The C_d for a flat plate is around 1, while more streamline bodies have a C_d less than 1.0.

The weight of a parachute and its payload doesn't change in any real way for a descent from near space. Since the drag force (F_d) must equal the parachute and payload weight, as the air density (ρ) increases, the velocity squared must decrease in proportion (assuming C_d and A for the parachute don't change appreciably during the descent). This indicates the square root of the parachute's descent speed is inversely proportional to the air density.

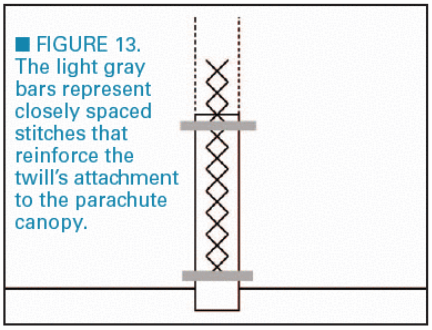
Source: **http://en.wikipedia.org/wiki/Drag_coefficient**

the tapes wrap around the end of the canopy and into the inside of the parachute. Now you can sew the seams between gores and their reinforcing tapes together. There should be a small loop at the bottom of the parachute where the twill tape was wrapped around.

Now sew the twill tape onto the canopy. As it's sewn, the sewing machine is also sewing the gores together. The ends of the twill tapes must be sewn extra strong. Wrap the end of the twill tape around the underside of the canopy and run extra stitches through it and the canopy as illustrated in Figure 13. That's it for making a parachute canopy. The next column will discuss the shroud lines and the parachutes spreader ring. There will also be a recovery aid to attach to the parachute.



■ FIGURE 12. Images — recorded every 1/3rd of a second — showing the opening of a deployed parachute. The fully deployed parachute appears at the top of the frame and looks like a semicircle with a zig-zag edge.

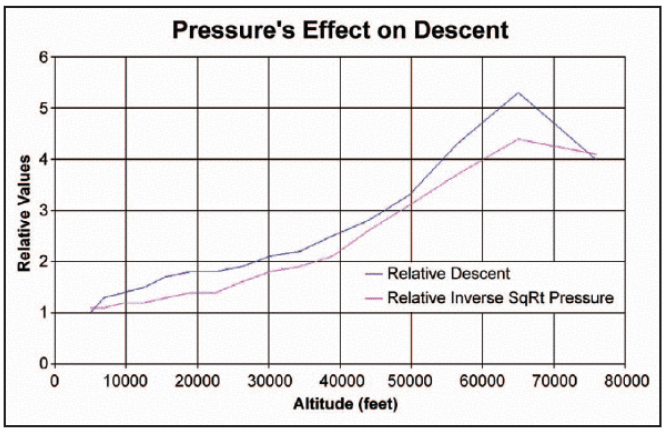


■ FIGURE 13. The light gray bars represent closely spaced stitches that reinforce the twill's attachment to the parachute canopy.

A PARACHUTE DESCENT FROM NEAR SPACE

Let's look at two aspects of parachute performance in the near space environment. First, a parachute returning from near space experiences an extreme change in air density and pressure. A parachute deployment at 100,000 feet takes place at an atmospheric pressure of 10 mb, or 1% of the average air pressure at sea level (1,013 mb). As the parachute descends, the air density becomes greater and the parachute becomes more effective at slowing the payload down. The parachute's drag — and therefore its ability to slow a payload down — depends on the air's density. So, let's compare a parachute's descent speed as a function of atmospheric pressure to see if it agrees with the equation for drag.

A parachute descends at a speed where the drag it creates is equal to the weight of the parachute and its payload. When the two oppositely directed forces are equal, there is no net force acting on the parachute and therefore, it experiences no acceleration. A constant velocity is the result of no acceleration. Now according to the equation for drag, the force a parachute experiences is proportional to its speed and to the square root of the air density. Using data from a previous near space mission, I created a chart comparing the square root of the air pressure (a good surrogate for air density) and the near spacecraft's descent speed as a function of altitude.



■ FIGURE 14. Not a bad match. The descent speed of a parachute does vary proportionally to changes in air pressure (and density).

To get both lines to appear together on the chart, I just plotted the relative change.

Second, even though the balloon burst occurs in a near vacuum, the parachute opens fully within two seconds. The image strip in Figure 12 is a series of stills from a video recorded at 98,000 feet. The images show that indeed the parachute does fully open within two seconds of the balloon burst.

Let's assume the near spacecraft behaves as if it's in free fall with no significant drag for the first two seconds after balloon burst. At the point of burst, the near spacecraft is ascending at a speed of 1,000 fpm, or 17 fps. According to the equations of motion for a mass under uniform velocity and acceleration ($d = vt + \frac{1}{2}at^2$), the near spacecraft will fall, $17t + (1/2)(-32)t^2$, or $17*2 + (1/2)*(-32)*2^2$, 34-64, or 30 feet from burst altitude.

The equation for speed is $v - at$, and this indicates the near spacecraft is falling 17 – 32*2, 17-64, or 47 fps by the time the parachute finally opens. This is equal to a descent speed of 32 mph. In high altitude balloon bursts, the near spacecraft falls at a speed between 70 and 100 miles per hour. Therefore, it appears a parachute doesn't do much initially, other than keep the near spacecraft from flipping over and tangling.

Onwards and Upwards,
Your near space guide **NV**

USEFUL WEBSITES

Additional information about parachutes can be found at these websites.

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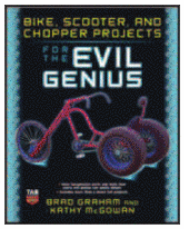
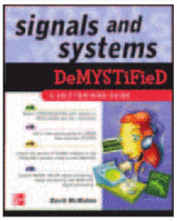
"EDITOR'S PICKS"



Bike, Scooter, and Chopper Projects for the Evil Genius

In this eco-conscious time, everyone is taking a second look at alternative forms of transportation that are both easy on the wallet and the environment. Notable in this book are several electric bike designs that can provide the basis for serious transportation. **$24.95**



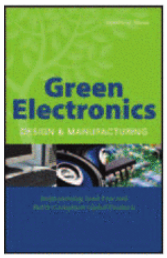
Signals and Systems Demystified

Working in the time domain can get you only so far in filter and communications systems design. *Signals and Systems Demystified* provides a gentle introduction to the frequency domain tools – such as the Fourier Transform – used by engineers tackling real-world problems. For intermediate to advanced readers. **$19.95**

Editor Bryan Bergeron's recommended reads.
Find these and many more great titles in the *NUTS & VOLTS* Webstore!

NEW!

Green Electronics Design and Manufacturing
by Sammy G. Shina
Pub.Date 04/17/08



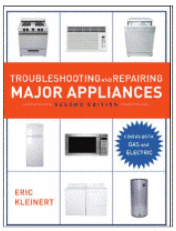
This state-of-the-art resource brings together contributions by a team of experts from the total electronics supply chain who show how to master the strategy, design, test, and implementation issues of meeting global environmental regulations. Edited by the founder of the New England Lead-Free Consortium and filled with over 130 detailed illustrations
Reg. $99.95 **Sale Price $79.95**

ELECTRONICS

Beginner's Guide to Embedding C Programs
by Chuck Hellebuyck

The C language has been covered in many books but none as dedicated to the embedded microcontroller beginner. Through his down-to-earth style of writing, Chuck Hellebuyck delivers a step-by-step introduction to learning how to program microcontrollers with the C language. In addition, he uses a powerful C compiler that the reader can download for free in a series of hands-on projects with sample code so you can learn right along with him. For the hardware, he found the best low cost but effective development starter kit that includes a PIC16F690 microcontroller and everything else the beginner needs to program and develop embedded designs. **$39.95**

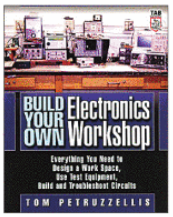
Troubleshooting and Repairing Major Appliances: 2nd Edition
by Eric Kleinert



Now covering both gas and electric appliances, the updated second edition of *Troubleshooting and Repairing Major Appliances* offers you a complete guide to the latest tools, techniques, and parts for troubleshooting and repairing any appliance. Packed with over 200 illustrations, the book includes step-by-step procedures for testing and replacing parts, instructions for reading wiring diagrams, charts with troubleshooting solutions, advice on using tools and test meters, safety techniques, and more. **$59.95***

Build Your Own Electronics Workshop
By Thomas Petruzzellis

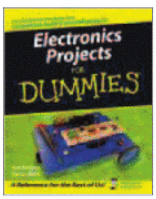
YOUR DREAM ELECTRONICS LAB IS WAITING INSIDE!



This value-packed resource provides everything needed to put together a fully functioning home electronics workshop! From finding space to stocking it with components to putting the shop into action — building, testing, and troubleshooting systems — popular electronics author Tom Petruzzellis' *Build Your Own Electronics Workshop* has it all! And the best part is, this book will save you money, big time! Reg **$29.95** **Sale Price $24.95**

Electronics Projects For Dummies
by Earl Boysen & Nancy C. Muir

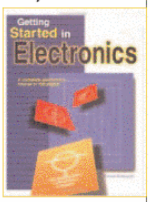
NEW!



Who says the Science Fair has to end? If you love building gadgets, this book belongs on your radar. Here are complete directions for building 10 cool creations that involve light, sound, or vibrations — a weird microphone, remote control gizmos, talking toys, and more, with full parts and tools lists, safety guidelines, and wiring schematics. **$24.95**

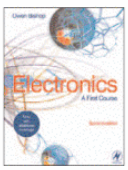
Best Seller

Getting Started in Electronics
by Forrest M. Mims III



Author Forrest Mims teaches you the basics, takes you on a tour of analog and digital components, explains how they work, and shows you how they are combined for various applications. Includes circuit assembly tips and 100 electronic circuits and projects you can build and test. Forrest M. Mims, III, has written dozens of books, hundreds of articles, invented scientific devices, and loves to share his knowledge with eager students! **$19.95**

Electronics: A First Course Second Edition
by Owen Bishop



Electronics: First Course starts with the basics of electricity and component types, and introduces students to practical work almost straightaway. No prior knowledge of electronics is assumed. The second edition now has additional applicability to BTEC First Electronics from Edexcel with coverage of fundamental topics required by students of this qualification, as well as other essential new topics that reflect recent technological developments. **$36.95**

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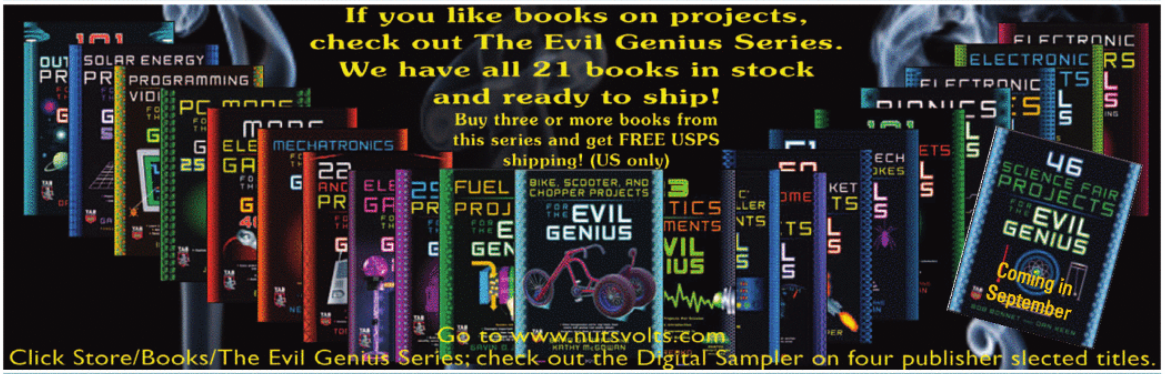

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BOOK & KIT COMBOS

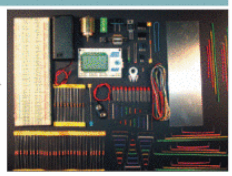
Virtual Serial Port Cookbook
by Joe Pardue
As talked about in the *Nuts & Volts* June issue,
"Long Live The Serial Port"

Book **$44.95**
Kit **$69.95**

This is a cookbook for communicating between a PC and a microcontroller using the FTDI FT232R USB UART IC. The book has lots of software and hardware examples. The code is in C# and Visual Basic Express allowing you to build graphical user interfaces and add serial port functions to create communications programs.

The Virtual Serial Port Parts Kit and CD
(also *available, above right*)
Combo Price $115.95 Plus S/H $8.95

From the Smiley's Workshop
page 55
C Programming for Microcontrollers
by Joe Pardue



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Do you want a low cost way to learn C programming for microcontrollers? This 300 page book and software CD show you how to use ATMEL's AVR Butterfly board (*available in the kit, above right*) and the FREE WinAVR C compiler to make a very inexpensive system for using C to develop microcontroller projects.

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by K. F. Ibrahim

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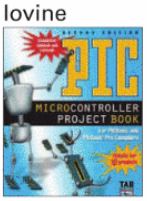
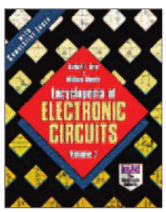
PIC Microcontroller Project Book
by John Iovine



The PIC microcontroller is enormously popular both in the US and abroad. The electronics hobbyist market has become more sophisticated. This new edition is fully updated and revised to include detailed directions on using both versions of the microcontroller, with no-nonsense recommendations on which is better served in different situations. **$29.95**

Encyclopedia of Electronic Circuits, Volume 7
by Rudolf F. Graf / William Sheets
Publish Date: August 31, 1998



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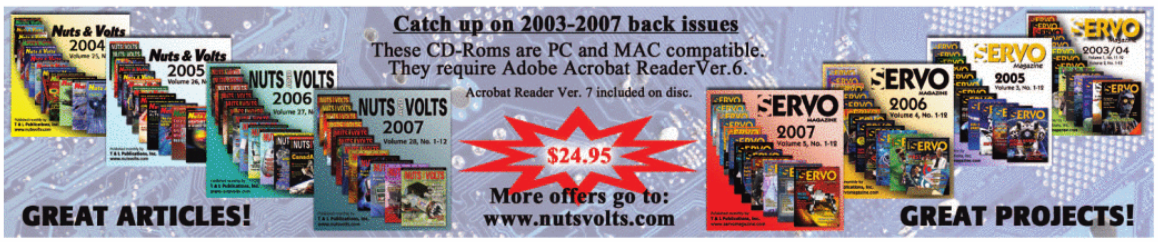

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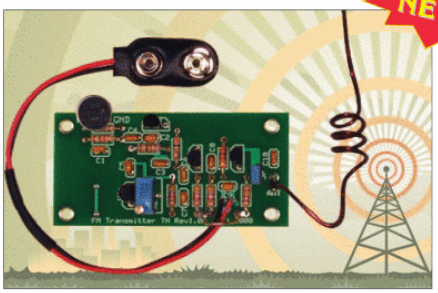

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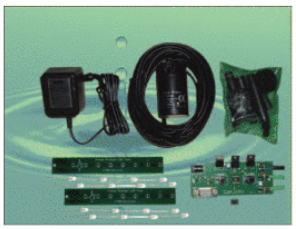
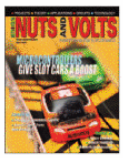


As seen in the May 2008 issue



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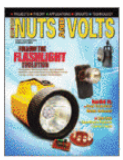

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As seen on the February 2008 cover

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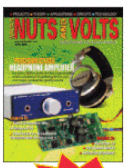

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October 2006

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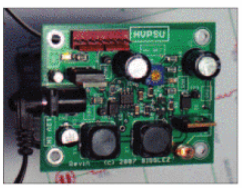

As seen on the April 2008 cover

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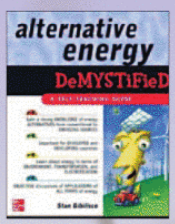
ALTERNATIVE ENERGY SECTION

Alternative Energy Demystified
by Stan Gibilisco
Publish Date: October 23, 2006



The fast and easy way to get up-to-speed on alternative energy. Because of current events, geopolitics, and natural disasters, the cost of fuel is front and center in our lives. This book provides a concise look at all forms of energy, including fossil fuels, electric, solar, biodiesel, nuclear, hydroelectric, wind, and renewable fuel cells. You will get explanations, definitions, and analysis of each alternative energy source from a technological point-of-view. **$19.95**

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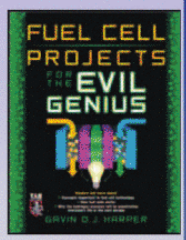
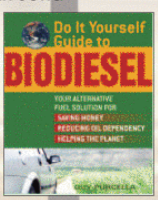
Fuel Cell Projects for the Evil Genius
by Gavin D. J. Harper



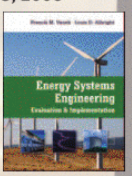
MORE THAN JUST SLIGHTLY EVIL: SAFE, INEXPENSIVE, EDUCATIONAL, AND FUN! *Fuel Cell Projects for the Evil Genius* is a fun and environmentally-aware project book for you — and the perfect follow-up to *Solar Energy Projects for the Evil Genius*. The book specifically focuses on projects involving fuel cells — technologies that generate electrical power whose only waste output is water. **$24.95**

Do It Yourself Guide to Biodiesel
by Guy Purcella



Contains the most current and complete information available for would-be biodiesel makers. This book offers a step-by-step path from the initial desire to do something good for the environment to the final stage of filling the tank with low-cost fuel. Readers are given a complete understanding of what biodiesel is and how to make it properly and safely. There is even a section on pitfalls to avoid, as well as the author's personal tips and tricks. **$15.95**

Energy Systems Engineering
by Francis Vanek, Louis D. Albright
Publish Date: June 13, 2008



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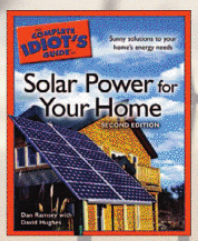

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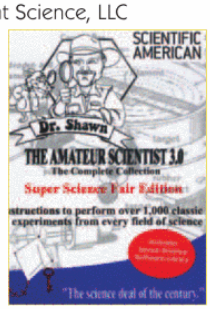

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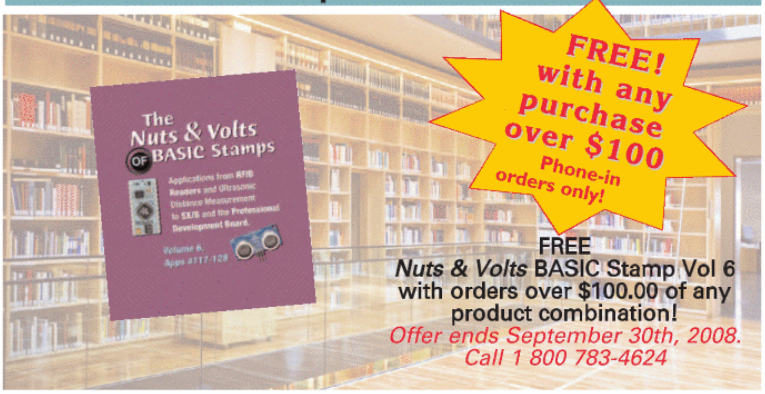

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All questions and answers should be sent by email to forum@nutsvolts.com All *diagrams should be computer generated and sent with your submission as an attachment.*

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2. Electronic Theory
3. Problem Solving
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>>> QUESTIONS

I live two miles south of the US border. My TracPhone only works reliably about 3/4 miles south of the border. At my residence, I can occasionally get just one bar on my phone. I would like to improve this. Is cell phone range limited by my transmit power or my receive distance?

Can I rig some kind of reflector/antenna/booster amp to improve the range of my phone, so I don't have to pay for international service?

#9081 G. Frank Humiston
via email

How do manufacturers specify parameters of passive components?

One example is a 1A diode. Is 1A the maximum current allowed, or is the diode guaranteed to pass 1A continuously? Another example is a resistor. When you use a resistor as a 20 mA current limit to an LED powered by 13.8V, isn't a 1/4W resistor pushed over the limit?

I actually limit LED current to anywhere between 15-18 mA. The LED is just as bright, but lasts much longer (lasts forever compared to our short lifetime). I had several of these "LED lightbulbs" burn out within a year due to bad design by their manufacturers.

#9082 Dusan
via email

I have several Maytag Neptune washing machine motors with the driver board.

I would like to make an adjustable speed generator so that I could use these motors on wood working tools. I was thinking that a 555 series chip would be the basis, but I don't know how to get the three phase output. Also, would I drive one or two phases of the motor at the same time?

One thought was to use the 555 to cut the power to one winding at a time sequentially and leave power on the other phases. I don't know how Maytag did this. I don't want to use a microprocessor chip if I can avoid it.

#9083 Bob McKnight
via email

Does anyone have a circuit or info to safely regulate high voltages from 200 volts to about 50 volts? Or how to cascade adjustable voltage regulators to add up their outputs to any desired high voltage to about 200 volts?

#9084 Todd Grigsby
via email

I need a way to find a break and/or weak connection in a radio dog fence.

Preferably some kind of signal injector with a radio signal strength meter that can help pinpoint breaks or poor splices in a wire.

#9085 Chris
via email

>>> ANSWERS

[#5083 - May 2008]

Has anyone hacked a digital camera and installed the sensor and minimum circuits into an old film camera like an old Nikon F or Leica M2 or M3? I've seen astrophotog guys hack a digital Canon EOS D30 and Rebel to remove the IR filter for IR photography ... I don't know which electronics I can safely clip out of the digital donor. (There are film camera nuts out there that would die to see this done.)

I've had little success taking apart digital cameras. I'm on my third (since 2001) and once they break I've tried to open the case out of curiosity. The internal circuits are tightly packed and use a lot of custom components that would be hard to use again.

A 35 mm mechanical film camera uses film at the lens focal plane to capture an image of 36 x 24 mm as described here: **http://tinyurl.com/ygss4j**. However, the active imager in a digital camera is much smaller, typically 4 mm to 16 mm diagonal, as indicated here: **http://tinyurl.com/yx6q3s**. Some form of relay lens would be required to convert the 35 mm size image to that of the salvaged sensor. This would not readily fit into the existing film camera outline, and would require access to precision machine tools for construction and alignment.

A brief history and description of digital camera resolution is given here: **http://tinyurl.com/4j65sz**. Overall, your project is not practical, but the digital camera technology is quite fascinating!

Peter Stonard
Campbell, CA

[#6082 - May 2008]

Several years ago, I'd seen a device that plugged into a laptop's modem port and then to the headset port of a cell phone, and presto – an Internet connection! All that I can figure out is the interface device must have somehow produced a tone for the modem to believe it had a live line. From there, it was a simple matter of pushing 'speed dial' on the cell phone and away you went – surfing. Do you have any ideas about this and how it could be built from scratch? Better yet, could there be something built that would handshake between the data or USB port?

What you are looking for is simply a cellular capable modem, which can be installed in parallel to your existing modem if it is not cellular ready. I used an IBM P/N 85H8059 FRU 38H5062 PCMCIA data/fax modem card on an older laptop which was cellular capable, but you need an adapter cable for the specific cell phone. You should be able to pick one up used or surplus for very little money. Look for Cellular Ready ("Spectrum Connected") on the back of the modem card. You will also need a PCMCIA port on your computer. It had a max speed of 33.6 kbps, but I think there was also a faster, later one at 56 kbps from IBM.

Walter Heissenberger
Hancock, NH

[#7081 - July 2008]

My furnace/air conditioning servicer recently replaced the control unit in my high-efficiency furnace. The defective portion of the control unit turned out to be the spark generator, but, in the process I see the unit has a single-wire electric flame sensor, not the old standard thermocouple. I can't figure out how the thing works. Can someone please enlighten this old-timer?

In the old days of gas heating appliances, a pilot flame was used to start the main burners when heat was required. Typically, this pilot was started by a match or a spark generator. A thermocouple was used to check for the presence of the pilot flame by detecting its heat. If the thermocouple failed or did not detect heat, the main burners would not fire.

In today's energy conscious times, standing a pilot 24/7 to light the main burners is a waste of fuel. To save energy, appliance manufacturers now wait for a demand for heat, light the pilot flame, check for a pilot flame, and then open the main burner valves. Some schemes don't have pilots and directly spark the main burners. In either case, detection of a good flame is the key to safe burner control.

The single wire detection method is viable because a flame acts like a diode electrically. By expressing low voltage AC across the sense wire and detecting half wave rectification, the ignition module can deduce the presence of a good flame. Some ignition modules use the high voltage spark wire as the sense wire thus eliminating the need for a separate flame sense wire. The secret here is the flame is a diode. No flame, no diode, no rectification, no heat, and hopefully no raw gas vapor in your cellar.

John P. Gardner
Franklin, NH

[#7082 - July 2008]

Can a security system be built that would utilize a switch on a door to trigger a cell phone to call a number? A similar system on the Internet costs around $300. Can something be built for less than $100 with a "pay as you go" wireless phone?

Cellular phone electronics can be purchased as modules, for "m2m" (machine to machine) links over the cellular phone network which allows construction of hobby projects. For example, the GM862 made by Telit and sold through SparkFun Electronics (**www.sparkfun.com**).

A GSM SIM card is required to activate the phone which uses AT style modem commands for control and will send and receive data streams, SMS text, voice, or data up to 57.6 kbps. The module is compatible with standard international GSM cellular phone bands and SIM carriers in the USA (AT&T, Cingular, and T-Mobile). For a switch closure activated alarm, the GM862 will only need a simple microcontroller and a power supply. The module sells for about $150.

Peter Stonard
Campbell, CA

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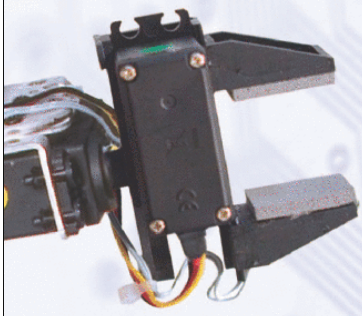

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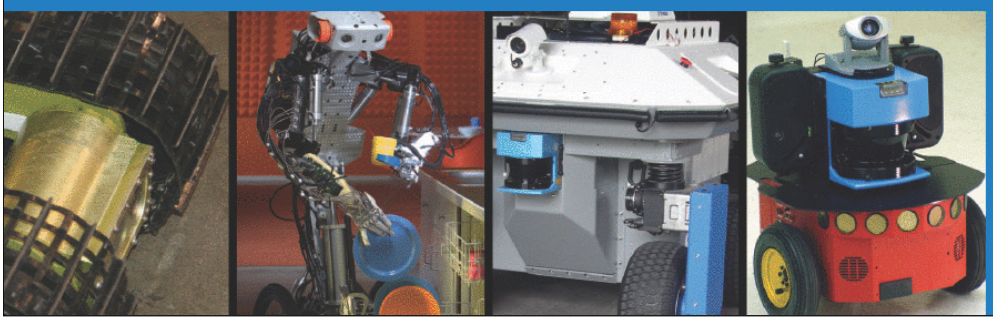

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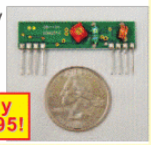

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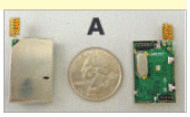

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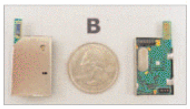

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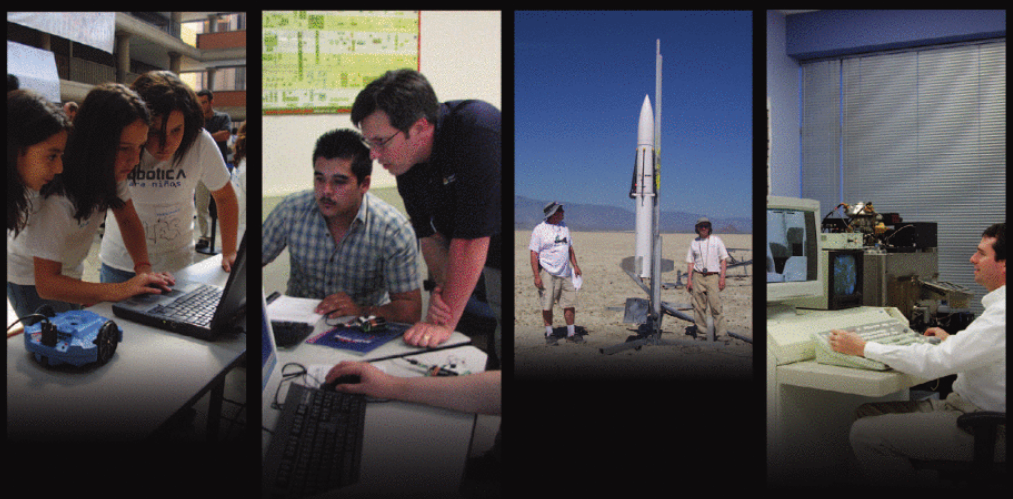

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